Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

aS21
.A75U5
Cop.2

Proceedings of the 8th

National Conference on Wheat Utilization Research

Denver, Colorado
October 10-12, 1973

ARS W-19
SEPTEMBER 1974

WHEAT
UTILIZATION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

THE EIGHTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH was held October 10 to 12, 1973, at the Albany Hotel, Denver, Colorado. Honorable Ted Strickland, Lieutenant Governor of Colorado, welcomed the attendants.

The objectives of the biennial conference are to provide a forum for reviewing the current status of wheat utilization research and to provide an opportunity to exchange information and ideas and to discuss problems of all segments of the wheat industry with the overall purpose of improving the economics, quality and quantity of wheat usage.

Sponsors of the Conference were Agricultural Research Service, U.S. Department of Agriculture; Great Plains Wheat, Inc., and affiliated State agencies; Millers' National Federation; National Association of Wheat Growers; and Western Wheat Associates, U.S.A., Inc., and affiliated State agencies.

Speakers and their organizations are responsible for the information they have contributed, and they should be consulted by those who may wish to reproduce their speeches, wholly or in part. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. Reference citations, figures, and tables are reproduced essentially as they were supplied by the author of each paper.

This report was edited by D. A. Fellers and prepared at the Western Regional Research Center, ARS, USDA, Albany, CA 94710. Copies are available upon request.

Program Committee

David A. Fellers, Chairman

Kenneth Gilles
Joseph Halow
Frank Hepburn
William Hoover
Klaus Lorenz
Cap Mast
Paul Mattern
Max Milner
Jerry Rees
Wilbur Schaefer
Fred Senti
Eugene Vickers
Edith Weir

Local Arrangements and Tour to Colorado State University, Fort Collins (Animal Research Facilities, Department of Agronomy, High Altitude Lab and National Seed Storage Lab)

Tom Mick
Klaus Lorenz
Lee Bronson

CONTENTS

Wheat Enrichment and Fortification--World Needs and Attitudes
Irwin Hornstein 3

Nutritional Significance of Trace Elements Occurring in or Added to Wheat
E. R. Morris 8

Cereal Grain Enrichment Program--A Look to the Future
R. O. Nesheim 13

Nutritional Labeling, Wheat, and the Nutrient Data Bank
R. L. Rizek 17

Removal of Heavy Metals from Waste Waters with a Starch Xanthate-Cationic Polymer Complex
R. E. Wing 26

Potentially Useful Products Derived from Gluten Hydrolyzate
K. Gutfreund and T. Yamauchi 32

Agricultural Alcohol in Automotive Fuel--Gasohol
Wm. A. Scheller 39

Insulation Materials Derived from Carbonized Expanded Cereals
V. R. Riley 43

Flavor Contributions and Characteristics of Raw and Processed Wheat Fraction Components
J. A. Maga and K. Lorenz 52

Precursors of Bread Flavor
J. A. Johnson 57

Status of High-Protein Bread
J. A. Shellenberger 61

High-Protein Bread Flour Blends for Government Purchase
M. M. Bean, D. K. Mecham, M. M. Hanamoto, and D. A. Fellers 64

Inert Atmospheres: A Substitute for Conventional Chemical Fumigation
C. L. Storey 71

Composition and Functional Properties of Milled Fractions of Triticale
R. A. Anderson, A. C. Stringfellow, and J. S. Wall 74

A Close Look at What Happens When Water is Added to Wheat Particles
J. E. Bernardin 81

Whole Wheat Fractionation Process
W. Henry and G. V. Rao 84

Preparation and Properties of Protein Concentrates by Wet-Processing Wheat Millfeeds
R. M. Saunders, A. A. Betschart, M. A. Connor, R. H. Edwards, and G. O. Kohler 88

Wet Milling of Wheat and Oats by Alkaline Extraction
Y. V. Wu, K. R. Sexson, and J. E. Cluskey 93

Protein-Starch Separation in a Non-Aqueous Solvent
J. W. Finley and E. Hautala 97

Effect of Steam Conditioning and Heat Treatment on Durum Wheat Milling
A. Seyem, W. C. Shuey, R. D. Maneval, and D. E. Walsh 101

Agriculture and Industrial Energy
D. L. Miller 106

Soft Wheat--An Endangered Species?
D. M. Mennel 110

The Wheat Outlook
J. Naive 115

The Wheat Situation as Seen by an Agronomist
L. P. Reitz 116

List of Attendees 123

WHEAT ENRICHMENT AND FORTIFICATION--WORLD NEEDS AND ATTITUDES

Irwin Hornstein
Office of Nutrition, Technical Assistance Bureau,
Agency for International Development

Before one can adequately discuss the improvement of wheat protein quality by fortification with amino acids and/or protein concentrates the rationale for improving dietary protein in the Less Developed Countries (LDCs) must be considered. The key questions to be answered are:

(1) Does protein malnutrition exist in the LDCs?

(2) If it does exist, why? and what alternatives are available for supplying more protein?

(3) When is fortification a viable solution?

All evidence indicates that protein/calorie malnutrition exists in the LDCs and is most damaging to the pre-school child. Statistically, two-thirds to four-fifths of all deaths that occur in the LDCs are within this group. Some 30% of children in the LDCs fail to reach the age of five. Chronic protein deprivation is to a great degree responsible for many of the deaths that are officially attributable to dysentery, measles, pneumonia, etc. Infections which are rarely fatal to well nourished children, when compounded by chronic protein deficiency, often result in death for the malnourished child. For example, recent studies by the Pan American Health Organization show protein/caloric malnutrition to be either the primary cause or a major factor in over 50% of the deaths of 1 to 4 year olds in Latin America.

The infant is also affected by the nutritional status of the mother. The need for protein materially increases during pregnancy. If these requirements are substantially unmet, the percentage of children carried to term decreases. Further, the birth weights of many of the offspring that do reach term are low and correlates with poor survival rates as compared to normal weight babies. There is litte argument that protein deficiency exists in the LDCs and that pre-school children and pregnant women are the most vulnerable groups.

Why is there a protein problem? Animal protein is well utilized. The essential amino acid composition of meat, fish, eggs and milk conforms closely to the needs of man. On the other hand, cereal proteins are low in some of the essential amino acids—wheat is deficient in lysine; corn in lysine and tryptophan, rice in lysine and threonine. In addition the digestibility of cereals can be poor and the net protein utilization of many of the cereals may be only 60% of that of animal protein.

The conversion of vegetable to animal protein is inefficient and therefore expensive. Animal protein is generally a luxury unavailable to the poor in the LDC's except in regions where hunting or fishing provides a part of the food supply. Thus, some 2 billion people in the LDCs depend on cereal grains for most of their calories and proteins. FAO in its third world survey reported that the daily dietary intake of these 2 billion people averaged approximately 2,200 calories and 58 grams of protein. Nine of the 58 grams of protein were derived from animal sources. According to FAO/WHO report on energy and protein requirements these figures correspond closely to the protein/calorie requirements for an LDC population subsisting mainly on cereals. This presents an apparent contradiction since protein malnutrition is a major problem in the LDCs.

Calorie Sufficiency and the Protein Problem. Based on FAO data, it would appear that if enough calories are provided in a cereal based diet to meet requirements protein deficiency vanishes. This argument has been advanced by nutritionists such as Gopalan who have also pointed out that calories are often more deficient than protein and that supplying more calories from conventional sources will furnish all the required protein. Furthermore, providing additional calories will permit increased utilization of protein as protein rather than as an energy source. How valid is this argument?

(1) FAO/WHO protein requirements are based on the needs of healthy "normals". These requirements underestimate the protein needs of the chronically undernourished who are frequently subject to infection and have need for increased amounts of protein during recovery.

A further problem with respect to the very small child is that the actual bulk of the food he can ingest in the form of tubers or cereals during the course of a day limits the amount of protein he consumes.

To cite an extreme case, let us look at a 2 to 3 year old in the northeast of Brazil where the major food staple is cassava. Energy/protein daily requirements for normal, healthy 2 to 3 year olds are about 1,350 calories and 16 grams of protein. Approximately 400 grams of cassava would meet the child's energy requirement but only 1/2 of the protein requirement even if the protein were totally utilizable. The small child cannot eat enough cassava to meet his protein needs.

It is informative to look at the growth pattern for LDC children as compared to that of children in the developed countries. Average growth is similar for the 2 groups until 6 months of age then the growth rate for the LDC children quickly drops below that of the norms of children in the developed countries--and there is no subsequent catch up--if they survive. This lower growth rate starts at weaning when the child's immunity drops and he is exposed to a hostile environment that leads to one bout after another with a variety of infections. The child never recovers his normal growth since there is never enough protein in the diet to make up for the metabolic losses during the illness.

(2) If the average protein consumption is barely adequate for the entire population, it is inadequate for at least the poorer 50%, and the lower the family income the less relevant are the average figures. Furthermore, food distribution within a family is not based on need. The father will often preferentially receive the aesthetically more desirable high protein foods and the younger children will receive proportionally less of these foods.

Paradoxically, increasing affluence may make the situation worse for those who do not share in this "affluence". People generally like meats and if they have the opportunity will eat far more than necessary. Witness the results in the world around us, grains and legumes are being converted at an increasing rate to animal protein and both the price of meat and of grains have sky rocketed. Some LDCs that do not produce enough grains for their own population are using both the land and the grain to produce livestock for export--and the poor with little income flexibility have even less.

One must conclude that despite an average dietary intake of protein and calories that is adequate on a worldwide basis, the facts of income inequalities, increased affluence in the developed world, poor distribution of protein foods within the family, requirements underestimated because based on needs of healthy individuals, and the low protein content in the diets of children all contribute to protein malnutrition in the real rather than the average world.

Increasing Protein In Cereal Diets. If increasing the utilizable protein content of the basic cereal grain diets of the people in LDCs is accepted as a valid goal, what are the available alternatives for supplying more protein?
(1) Increasing income. All efforts to bring about nutritional improvements must take into account that incomes in the LDCs are too low to provide foods with adequate protein. Calculations made by Patrick Francois show how long range this approach really is. He assumed a real 1.7 percent/year increase in per capita rural income over a 13-year period. In his example, income increased over this 13-year period from $52 to $65 and as a result per capita protein consumption increased less than 5%; animal protein consumption increased less than 2 grams/day. Nutritional improvement as a result of increased income must be considered unattainable in the short term.
(2) If increasing income is not a viable solution, we are left with a limited number of technological alternatives. These include:

(a) Improving the quality and/or quantity of protein in cereal grains by breeding--witness the development of high lysine maize and high protein wheat.

(b) Developing new and unconventional protein sources. Examples include oilseed protein, single cell protein, and fish protein concentrates. These are not foods per se but are best used as concentrates that are added to basic food staples to increase their protein content.

(c) Improving the utilizable protein in basic food staples (diets) by adding essential amino acid(s) that are deficient.

(d) Educating LDC populations via mass media and non-formal education approaches to modify food habits, e.g., to consume more of legumes that are already being grown and utilized.

All of these approaches have merit; they are not mutually exclusive. The approach to be used to add protein to the diet is dependent on regional resources and community life styles. Some of the questions to be considered as to whether fortification is feasible in a given region are:

(1) Is there one food staple that is the major source of calories?

(2) What foods can be fortified?

(3) Are potential fortificants available indigenously or must they be imported?

(4) Is the food processed centrally or in village mills dispersed throughout the countryside?

(5) Are appropriate points of intervention identifiable?

(6) Is the food usually milled or is its integrity maintained until consumed?

(7) Can the target group be reached via fortification?

(8) What fraction of the fortified food will reach the target group?

Acceptability problems are generally minimal if protein quality is improved by amino acid fortification but may be more of a problem when protein concentrates are used. Sufficient protein concentrate must be added to have a nutritional impact and if acceptability is adversely affected, new technology must be developed to overcome the problem.

The ability to incorporate other nutrients may be most important. Proper utilization of improved protein quality may depend on proper balance of minerals and vitamins in the diet. Solving the scientific-technological problems of increasing nutritive value via fortification constitutes only the first critical step. In order to translate fortification into durable programs that can have an impact, many inputs such as a willingness on the part of governments to subsidize fortification costs and to provide a reasonable monitoring system may be required. Other problems or disadvantages that must be considered are:

(1) Potentially limited coverage of rural areas.

(2) Expensive in terms of per capita cost of reaching target group.

(3) A fortification program is open ended. Fortificant must be added as long as the food staple is to be improved.

Wheat Fortification with Lysine or Protein Concentrates. What can one expect from the addition of lysine to wheat? Studies by a number of workers have demonstrated that the growth response of children receiving lysine supplemented diets is superior to that of the control group. Since methodologies varied, results also varied and observed improvements ranged from marginal to substantial. For example, Pereria et al. added L-lysine at the 0.25% level to wheat consumed by 2-to-5 year old children in an orphanage during a six month period. The basal diet (wheat, pulses, oil, vegetables, fruit, sugar and spices) provided 2 grams vegetable protein and 100 calories per kilogram body weight per day. Foods were prepared by boiling, roasting and/or frying. The children on the non-fortified diet had a daily lysine intake of 0.68 grams. The children on the supplemented wheat consumed an additional 0.37 grams lysine per day. The average increase in height was 3.26 centimeters in the lysine group and 2.61 in the control group. A significant but not startling result.

Graham, in clinical studies at the British American Hospital in Lima, Peru, studied the effect on rate of weight gain in infants when fed unfortified wheat flour or wheat flours containing an equivalent of 0.11% added lysine, 0.18% added lysine and 0.36% added lysine as the sole source of protein. The rate of weight gain using casein as the protein source was given a value of 100. The rate of weight gain was 53% of the casein value for unfortified wheat flour, and 90-99% of the casein rate when lysine fortified wheat flour was used.

Hegsted found that the net protein utilization of white flour was raised from 4% protein to 7% protein by the addition of 0.3% lysine. The addition of 0.3% lysine was equivalent to adding 3 grams of utilizable protein to every 100 grams of white flour. Thus, for every gram of lysine added 10 grams of protein was returned. And to produce this extra protein required no change in agronomic practices or new lands to be cultivated. These clinical and laboratory results, interesting as they are, will not convince a government planner that millions should be invested in a wheat fortification program. He must ask, "What can be expected under actual living conditions?"

Lysine Fortification Study in Tunisia. The United States Agency for International Development (A.I.D.) initiated a pilot lysine wheat fortification project in Tunisia, under the direction of Dr. Fredrick Stare of Harvard University, to determine whether fortification of wheat is logistically feasible and/or nutritionally significant for large populations. Villages bordering the Sahara Desert in southern Tunisia were chosen as the test site. Three ethnic groups, Arab, Berber and Negro live in the area. The mean monthly family income is approximately $30-$40. Rainfall is less than 4 inches per year and agriculture is quite limited. Harvesting of dates is the major occupation. Infant mortality is estimated at about 20% of all live births, the majority of deaths occuring in the first months of life. Infants are generally breast-fed until 2 years of age.

Wheat is the main dietary staple providing more than 60% of calories and over 70% of the daily protein intake. No wheat is grown in the area. The wheat products consumed are milled in northern Tunisia. All aspects involved in milling, distribution and sale of wheat products are under government control. Twelve villages with a population of approximately 16,000 and a pre-school child population of about 3,000 have been divided into 3 study populations. One group received unfortified wheat; a second group wheat, supplemented only with vitamins and iron and a third group receives vitamins, iron and lysine. The study is designed to evaluate the effects of fortification of wheat products (consumed as cous cous, bread and pasta) on the development of pre-school children. At six-month intervals all children in the study are examined. Standard anthropometric measures, bone maturation and linear growth, hematologic states and a few urinary and serum measurements of nutritional status are made at each examination. In addition a weekly census is conducted on births and deaths, and a detailed 5-day dietary survey of food consumption of representative families is carried out.

The various fortification nutrients are sent by manufacturers to Minneapolis and are premixed at a Pillsbury plant. The two types of premix are shipped to Tunis and delivered to appropriate mills where cereal products are fortified at predetermined rates. Bags of enriched product are identified by color coded labels and strings and then shipped by truck to appropriate warehouses from which they are purchased by storekeepers from individual villages. The fortification test program has been active since mid-June 1971. The ingredient cost of fortification has been calculated by Robert Wooden of Pillsbury and is shown in Table 1.

Table 1.--Lysine, vitamin and mineral premix ingredient cost

Item	%	$/Lb	$/cwt Premix	% Ingredient cost
Vitamin A	1.04	5.97	6.21	7.43
Vitamin D	0.026	11.36	0.29	0.35
Vitamin B_1	0.193	6.36	1.23	1.47
Vitamin B_2	0.119	12.73	1.52	1.82
Niacin	1.35	1.70	2.30	2.75
Iron	1.184	0.42	0.50	0.60
Lysine monohydrochloride	60.0	1.14	68.40	81.88
Starch	35.088	0.08	2.96	3.55
Tricalcium phosphate	1.0	0.14	0.14	0.16
			$83.55	

Added to wheat at 0.5%, ingredient cost to fortify 1 cwt of flour with lysine premix is 41.77¢. Drum and liner to package cwt of premix costs $3.25.

The ingredient cost to fortify 1 cwt flour with the lysine/vitamin premix is 41.77¢; with vitamin premix, 6.25¢. The difference is 34.2¢ for lysine and 1.32¢ for the added starch. The ingredient cost plus costs for packaging, labor, trucking and ocean freight for fortifying 100 pounds of flour with 0.5% of the lysine/vitamin premix to give 0.3% lysine monohydrochloride in the fortified flour is 51.1¢. Similar vitamin fortification costs are 7.13¢.

If these figures are translated into fortifying all of the flour produced by the 18 Tunisian major mills, it would cost approximately $4.5 million dollars to fortify their total output of 8.8 million cwt/year with the lysine/vitamin mix and approximately $630,000 for fortifying the entire output with vitamins and iron only. To supply the feeder system for adding the fortificants would cost an additional $1,000/installation. These figures do not include profits, quality control or administrative costs. The pre-fortification base line data has identified significant shortness in the child population by 2 years of age despite normal measurements at 3 and 6 months of age. In only 10% of the families did the per capita food consumption data meet the FAO recommendations. Significant nutritional impact data will not be available until the next round of measurements are made.

Incorporating Legume and Oilseed Protein Concentrates in Wheat Products. A.I.D. is also supporting a study on improving the nutritive value of wheat under the guidance of Dr. William Hoover of Kansas State University. The purpose of this project is to develop methodologies for preparing and incorporating protein concentrates derived from legumes and oilseeds into wheat flour at a high enough level to have a nutritional impact and still have the resulting baked or cooked wheat products be acceptable. The key factor is making the soy/wheat blends acceptable is the use of small amounts of an FDA approved emulsifier (sodium stearoyl-2-lactylate). Presumably other emulsifiers are available that may serve the same purpose. The most promising products resulting from this study are soy/wheat blends containing up to 15% soy flour (50% protein). Soy fortified flour is now a commodity available for distribution through the Food for Peace Program. It is available either as a 6% or 12% soy/wheat flour blend. The nutritional improvement in bread engendered by the addition of soy protein is shown in Table 2.

Table 2.--Protein quality and content in wheat/soy breads

Parameter	Wheat flour plus soy. Percent soy 0	6%	12%
PER (Protein Efficiency Ratio)	0.7	1.3	1.95
Protein content (approx), 35% moist. basis	8.0	10.0	12.0
Lysine content (as % of protein)	1.7	2.5	3.3

From the processing standpoint, there is little change in using the soy/wheat flour blend. The major changes are that a little more water must be added because of the greater water-holding capacity of the soy protein and mixing time is a little less. The shelf life of the soy fortified flour is similar to that of wheat flour and baked goods have a somewhat longer shelf life.

I am indebted to Dr. Hoover for supplying the following cost data for the 12% soy fortified wheat flour. At current Kansas City prices defatted soy flour cost $13.65 cwt and wheat flour costs $11.50 cwt. A mixture of 88 parts wheat flour, 12 parts of soy flour and 1/2 part of the emulsifier (cost 25¢) results in an ingredient cost in the blend of $11.95 per cwt. The difference is 45¢ per cwt, a 3.9% increase in price. (Additional costs for blending, handling, profits, testing and procedures to insure against government penalty discounts are substantial and are discussed in the paper by Bean _et al_. presented in later pages of this proceedings. The Editor). However, because of the greater water holding capacity of the soy protein the wet dough yield would be 6% to 7% more. The baker or housewife will obtain a greater number of loaves of bread for a given weight of the blended flour. The result is that the gain in "yield" tends to balance the increase in ingredient cost. Protein content of unfortified bread is increased from 8% to 12% in the fortified bread. Not only is protein content improved but wheat protein utilizability is increased because of the addition of the higher lysine containing soy protein.

Prospects for Expanding Wheat Fortification. If we assume that both amino acid and/or protein concentrate fortification of wheat prove nutritionally useful and logistically feasible and that the foods produced are acceptable to the consumer what is the prospect for fortification of wheat? A key determinant is cost. Data available is very preliminary and is based on ingredient cost and needed capital equipment. Support costs such as administrative and logistic costs have not been well established. Once this is done we are still faced with a complex problem. Who will pay for fortification? Probably the most logical assumption is that the consumer will pay. But if this is the case, will it reach the groups in greatest need. The impoverished purchaser may choose low price and low nutrition if faced with the choice of buying fortified wheat at a high price or unfortified wheat at a low price.

One possibility is for the LDC Government to decree that all the wheat be fortified, however, if the price is increased the consumer may increase his purchase of low cost less nutritious food. The problem of foreign exchange also clouds the picture. If fortificants such as amino acids or soy protein must be imported, LDC governments may be reluctant to assume this added foreign exchange burden. In short, at this point in time realistic feasibility is still undetermined. We have recently held a workshop in Tunisia where millers, bakers, and government personnel, all in key positions to implement fortification, met with scientists and food technologists. The purpose of this workshop was to explain the merits to these key LDC individuals and to work with those countries interested in implementing a fortification program. There will be a follow-up in several countries, perhaps a more definitive answer will be available in the next 2-3 years. I have tried to give a realistic "state of the art" report. Regretfully one cannot predict when fortified wheat or other food staples will become available in the LDCs. However, in view of increasing population pressures and the increasing demand for animal products, the time for fortification has arrived.

NUTRITIONAL SIGNIFICANCE OF TRACE ELEMENTS OCCURRING IN OR ADDED TO WHEAT

Eugene R. Morris
Nutrition Institute, Agricultural Research Service
U.S. Department of Agriculture

In 1970 the Food and Agriculture Organization reported that the United States population obtained approximately one-fourth of its total caloric intake from cereals (1). This rate of consumption is low in comparison with most other population groups of the world; nevertheless, cereals are a significant source of many nutrients as well as calories. Wheat in various forms makes up approximately three-fourths of the calories supplied by all cereals or slightly less than one-fifth our total caloric intake. The preliminary estimate for 1973 is that we, the United States population, will consume an average of 139 grams of wheat or about 0.3 pound per day, per person (2). Today we wish to discuss some of the nutritional implications of this 139 grams of wheat, specifically as relating to trace elements.

Much of the wheat is consumed as refined flour, in bread or other bakery products, and only a relatively small amount is consumed as whole wheat, predominantly as whole wheat bread and cereal. Table 1 is a summary of the concentration of some nutritionally important trace elements in wheat and flour milled from it (3, 4). With the exception of selenium, all the trace elements are in considerably lower concentration in flour than in the wheat from which it was milled. The wheats used in this study were commercial milling blends and some variation from these data will occur with individual wheat and flour samples. The recovery of the trace elements in flour, based on the percentage extraction supplied with the flour samples, is also given in Table 1. Much of the amount of the trace elements in whole wheat is not recovered in the refined flour, but leaves the mill in the germ, bran, and shorts, the latter two products going primarily into animal feeds.

Table 1.--Trace elements in commercial blends of hard wheat and flours of 55 to 65% extraction milled from them

	Iron	Zinc	Chromium	Copper	Selenium	Manganese
Whole wheat, ppm	44.4	24.0	0.38	5.1	0.50	37.9
Bakers patent flour, ppm	8.6	6.3	0.22	1.9	0.47	4.5
% recovered in flour	12.0	16.0	35.00	22.0	57.00	7.0

For the purpose of comparing the two extremes, the potential intake of trace elements as either whole wheat or unenriched white flour products is shown in Table 2. A person using whole wheat products exclusively would consume five times as much iron, four times as much zinc, almost nine times as much manganese and twice as much copper as one using unenriched flour products. The intake of chromium and selenium would be less than 0.1 milligram for either group of products. Recommended dietary allowances (RDA) have been established by the National Research Council for iron and copper (5) and the next revision will include a recommendation for zinc. The whole wheat dietary would supply one-third of the RDA for iron and copper and one-fifth of the RDA for zinc (Table 3). The unenriched flour dietary would supply less than one-tenth of the RDA for iron and zinc and a little more than one-sixth for copper. No RDA have been established for other trace elements. It is evident that consumption of more whole wheat products

Table 2.--Potential daily intake of trace elements from wheat products. Based on 139 grams of wheat/day

	Milligrams per day			
	Iron	Zinc	Manganese	Copper
All as whole wheat	6.2	3.3	5.3	0.7
All as unenriched flour	1.2	0.9	0.6	0.3

Table 3.--Potential percentage from wheat products of the recommended dietary allowances for trace elements. Based on 139 grams of wheat/day. RDA, adult female; 18 mg Fe, 15 mg Zn, 2 mg Cu

	Percent of RDA supplied		
	Iron	Zinc	Copper
All as whole wheat	34	22	35
All as unenriched flour	7	6	15

would bring the U.S. population to a higher level of trace element intake than that provided by highly refined unenriched flour products.

A portion of the minerals consumed in food by man and animals is not absorbed and passes into the feces. The RDA for the trace elements are established with this fact taken into consideration. For example, an average of about 10% of the iron consumed is actually absorbed; therefore the RDA for iron is set at 10 times the amount needed to be absorbed (5).

I would like next to discuss the availability of the trace elements in wheat, giving some of the research performed in the Vitamin and Mineral Nutrition Laboratory at Beltsville, and reviewing briefly work of others.

In our laboratory we have been interested in the bioavailability of iron in foods and recently have been studying wheat (6). We have used the rat as the bioassay subject, using the prophylactic maintenance of hemoglobin in the growing rat as the bioassay criterion. Relative biological values (RBV) from one set of experiments on commercial blends of hard and soft wheats are given in Table 4. The RBV is the response to the test material expressed as a percentage of the response to a reference compound, ferrous ammonium sulfate. The germ of both hard and soft wheat were equal to the reference salt, and all other fractions except the whole soft wheat had an RBV of 80 or above. The RBV of 65 obtained for the whole soft wheat in this experiment is the lowest value we have obtained on any wheat fraction. In an experiment just recently completed with this same lot of wheat, the value was closer to 80. The RBV ranged from 90-115 in previous tests using a different lot of hard wheat and milling fractions. It is possible that different varieties may have different bioavailabilities. These results show, however, that wheat is a source of highly available iron for the rat.

Table 4.--Relative biological value to the rat of iron in wheat.
RBV of ferrous ammonium sulfate is defined as 100

	Relative Biological Value	
Fraction	Hard wheat	Soft wheat
Whole grain	81	65
Bran	85	80
Germ	97	103
Shorts	81	---

Wheat is generally considered a poorly available source of iron for the human and a typical absorption value for native wheat iron was included in a recently published report by Cook et al. (7). This study was a cooperative effort between the University of Washington at Seattle, Washington University at St. Louis, and the American Institute of Baking in Chicago with financial support from the U.S. Department of Agriculture. Table 5 is a summary of some of the findings from this study. The absorption of wheat iron tagged hydroponically with radioiron was about one-third that of the reference ferrous ascorbate. The geometric mean absorption of the native wheat iron was 6.1%, less than the 10% absorption on which the RDA is based. The poor availability of wheat iron to the human is generally attributed to the phytic acid in wheat. There is phytase enzyme activity in the intestine of the rat and the question arises whether the breakdown of phytate enables the rat to utilize the native wheat iron. We tested a synthetic ferric phytate preparation in the rat bioassay and found the RBV to be about 40, much below

Table 5.—Absorption of iron from bread rolls by human subjects (7)

Test source	Absorption ratio[1/]
Native wheat iron	0.33
Sodium iron pyrophosphate	0.02
Ferric orthophosphate	0.07
Reduced iron	0.25
Ferrous sulfate	0.27

[1/] Absorption ratio = absorption of iron from test sources baked in rolls/absorption of iron from ferrous ascorbate solution.

the values in Table 4 for the various wheat fractions. Thus we suspect that phytate is not the explanation for the difference between the rat and the human in their ability to utilize wheat iron.

The utilization by human subjects of four forms of fortification iron baked into rolls is summarized in Table 5. Sodium iron pyrophosphate and ferric orthophosphate were poorly utilized, less than one-tenth as well as the reference ferrous ascorbate. The reduced iron and ferrous sulfate were utilized about one-fourth as well as the reference,* slightly lower than the native wheat iron. The reduced iron used in the study reported here had an average particle size less than 10 µ, smaller than the usual commercially available reduced iron. Unpublished results from our laboratory indicate that reduced iron of 10 µ or less has an RBV for the rat at least twice that of the commercially available material. A recent Association of Analytical Chemists collaborative rat assay is in agreement with our results (8). Thus, the findings of Cook et al. (7) for reduced iron may be somewhat high if applied to commercially available reduced iron.

An interesting observation reported by Cook and coworkers (7) was the effect of meat on the absorption of ferrous sulfate in rolls. When the rolls were eaten with a meal containing no meat only one-third as much iron was absorbed as when the rolls were eaten alone. When, however, the rolls were eaten in a meal that contained meat, the iron absorption was the same as when the rolls were eaten alone.

The chemical nature of the iron in wheat is not known except for cytochromes in the germ. We have found that about two-thirds of the iron in bran is extracted by molar sodium chloride solution. The iron compound or complex in the salt extract chromatographed on Sephadex gel filtration medium is a material with molecular weight less than 5000. A phosphorous containing material overlaps the iron, but its peak maximum does not exactly coincide with the iron peak. This phosphorous compound or complex has not been characterized, but evidently is not associated with the iron complex. The iron in the salt extract is in the ferric oxidation state. Efforts to isolate, identify, and bioassay this salt extractable iron in wheat are continuing. We have not yet studied the non-salt extractable iron. Hopefully these studies will help explain the availability of wheat iron and perhaps yield suggestions as to how wheat can be made a better source of iron for humans.

Most plant foodstuffs that contain phytate are not good sources of available zinc for animals. O'Dell et al. reported bioavailabilities of zinc in several foods to rats and chicks (9). The values for the cereal grains wheat and rice, and for two animal sources, egg yolk and fish meal, are given in Table 6.

Table 6.--Bioavailability of dietary zinc to rats and chicks (9)

Zinc source	Bioavailability (zinc carbonate defined as 100)	
	Rats	Chicks
Wheat	38	59
Rice	39	62
Egg yolk	76	79
Fish meal	84	75

---

* Ferrous ascorbate reference was prepared as a mixture of ferrous sulfate and ascorbic acid. It was fed as a solution of inorganic iron in the absence of food to subjects who had fasted overnight. It appears that wheat rolls impair iron absorption compared to the reference conditions even if the supplemental iron is from a high biologically available source such as ferrous sulfate. The Editor.

There is little difference in the bioavailability values for wheat and rice by the two species. The values for both cereal grains, however, are less than those for the two animal sources. Several recent reports by Reinhold and coworkers indicate that wheat is not a good source of zinc for humans (10-12). The zinc consumption of much of the rural Iranian population exceeds the 15 mg per day suggested as the adult human requirement. Yet, overt zinc deficiency occurs in the rural population and is very low in incidence in the more urban populations. The unleavened bread (tanok) made from high extraction wheat flour in rural villages was found to have almost twice as much phytate as the leavened breads (bazari or sangak) made in commercial urban bakeries. Zinc balances were found to be adversely affected by the consumption of phytate-rich bread. Zinc balance was markedly positive when villagers ate diets that contained about one-fourth the phytate they normally consumed. Reinhold interpreted this to mean that the subjects had been in poor zinc status while eating their usual unleavened bread diet. Whether the zinc in refined flour is more available than that in whole wheat flour, or whether the usual U.S. diet contains amounts of phytate detrimental to the total zinc intake is not known.

Information is sparse on the availability of the copper, chromium, selenium and manganese in wheat. Schultze, Elvehjem and Hart, in the early years of iron and copper research, concluded that the copper in wheat germ is readily utilized by the rat (13). Availability to humans of the copper in wheat is not known.

One form of biologically active chromium is glucose tolerance factor (GTF) (14). Toepfer, Mertz and coworkers have recently reported GTF activity in wheat (15). Approximately 40% of the chromium in wheat was extracted by 50% aqueous ethanol, and when tested in an in vitro bioassay, this extract was found to contain GTF activity. Relative availability of the chromium when consumed in the diet was not determined.

Scott and Cantor have calculated the biological availability of selenium in wheat to be 100% based on the prevention of exudative diathesis in the chick (16). Rats fed seleniferous wheat absorbed 64% of the selenium (17). To our knowledge no studies have been reported on availability of selenium in wheat to humans.

I am not aware of any studies on the availability of the manganese in wheat.

Discussion and Summary. It is readily apparent that greater consumption of whole wheat products will increase the trace element intake of the U.S. population. One-third to one-fifth of the RDA for trace elements could be supplied by whole wheat at the present rate of consumption of wheat products. This is of little or no real nutritional benefit, however, if the trace elements in wheat are poorly utilized.

The native iron in wheat is utilized well by the human in comparison with that in most other plant foods that have been tested (18). Some types of fortification iron are poorly utilized. Layrisse et al. have concluded that fortification iron added as a soluble iron salt to rolls, mixes with the nonheme iron pool of the meal consumed and its absorption reflects the absorption of the total nonheme iron (19). Thus, we would expect fortification iron to be utilized only to the same extent as the native wheat iron as it is further affected by the total meal consumed.

The zinc in wheat is not well utilized by man. Phytate is the suspect cause for this poor availability. We might raise the question, in the mixed diet consumed by most people in the U.S., "Do the wheat products consumed decrease the availability of zinc in the total diet to the point of nutritional importance?" Although the answer would seem to be "no", we do not know with certainty. Selenium and copper availability to humans may be inferred from animal experiments to be good. The practical implications of this inference as far as selenium is concerned are unknown. We need information on utilization of copper in wheat by man. Since a nutritional manganese deficiency in humans has not been demonstrated, there seems no pressing need for information on the availability of wheat manganese.

Although questions remain unanswered, and many have not even been posed in an experiment, we may conclude that wheat products are important in trace element nutrition.

Literature Cited

1. Aykroyd, W. R. and J. Doughty. Wheat in Human Nutrition. FAO Nutritional Studies No. 23, 1970.

2. U.S. Department of Agriculture, preliminary estimated 1973 wheat consumption data.

3. Zook, E. G., F. E. Greene and E. R. Morris. Nutrient composition of selected wheats and wheat products. VI. Distribution of manganese, copper, nickel, zinc, magnesium, lead, tin, cadmium, chromium, and selenium as determined by atomic absorption spectroscopy and colorimetry. Cereal Chem. 47, 720-731, 1970.

4. Hepburn, F. N. and J. H. Tulloss. Nutrient composition of selected wheats and wheat products. VIII. Contents of ash, iron, phosphorous, magnesium, potassium and sodium. Cereal Chem. (in press).

5. National Academy of Sciences. Recommended Dietary Allowances. Washington, D.C. Publ. 1694. 1968.

6. Morris, E. R., F. E. Greene and A. C. Marsh. The chemistry and bioavailability to the rat of the iron in wheat. Proc. TEMA-2, 1973. (in press).

7. Cook, J. D., V. Minnich, C. V. Moore, A. Rasmussen, W. B. Bradley and C. A. Finch. Absorption of fortification iron in bread. Amer. J. Clin. Nutr. 26: 861-872, 1973.

8. Fritz, J. C., G. W. Pla, B. N. Harrison and G. A. Clark. Collaborative study of rat hemoglobin repletion test for bioavailability of iron. To be presented at AOAC meeting, Oct. 9-12, Washington, D.C., 1973.

9. O'Dell, B. L., C. E. Burpo and J. E. Savage. Evaluation of zinc availability in foodstuffs of plant and animal origin. J. Nutr. 102: 653-660, 1972.

10. Reinhold, J. G. High phytate content of rural Iranian bread: a possible cause of human zinc deficiency. Amer. J. Clin. Nutr. 24: 1204-1206, 1971.

11. Reinhold, J. G., K. Nasr, A. Lahimgarzadeh and H. Hedayati. Effects of purified phytate and phytate-rich bread upon metabolism of zinc, calcium, phosphorous, and nitrogen in man. Lancet 1973, 1(7798): 283-288, 1973.

12. Reinhold, J. G., H. Hedayati, A. Lahimgarzadeh and K. Nasr. Zinc, calcium, phosphorous and nitrogen balances of Iranian villagers following a change from phytate-rich to phytate-poor diets. Ecology Food Nutr. 2: 1-6, 1973.

13. Schultze, M. O., C. A. Elvehjem and E. B. Hart. Further studies on the availability of copper from various sources as a supplement to iron in hemoglobin formation. J. Biol. Chem. 115: 453-457, 1936.

14. Mertz, W. M. Chromium occurrence and function in biological systems. Physiol. Rev. 49: 163-239, 1969.

15. Toepfer, E. W., W. Mertz, E. E. Roginski and M. M. Polansky. Chromium in foods in relation to biological acitvity. J. Agr. Food Chem. 21: 69-73, 1973.

16. Scott, M. L. and A. H. Cantor. Tissue selenium levels in chicks receiving graded amounts of dietary selenium. Fed. Proc. 30: 237 (Abstr.) 1971.

17. Anderson, H. D. and A. L. Moxon. The excretion of selenium by rats on a seleniferous wheat ration. J. Nutr. 22: 103-108, 1941.

18. Layrisse, M., J. D. Cook, C. Martinez, M. Roche, I. N. Kuhn, R. B. Walker and C. A. Finch. Food iron absorption: A comparison of vegetable and animal foods. Blood 33: 430-443, 1969.

19. Layrisse, M., C. Martinez-Torres, J. D. Cook, R. Walker and C. A. Finch. Iron fortification of food: Its measurement by the extrinsic tag method. Blood 41: 333-352, 1973.

CEREAL GRAIN ENRICHMENT PROGRAM -- A LOOK TO THE FUTURE

Dr. Robert O. Nesheim
Vice President - Research and Development
The Quaker Oats Company

From a historical standpoint, fortification of staple foods as a means of providing nutrients for which population groups were judged to be at risk had their origins in the late 1930's and early 1940's. Prior to 1936 only the additions of vitamin D to milk and iodine to table salt had the approval of the Committee on Foods of the American Medical Association. On January 1,1941, a standard of identity providing for nutrient fortification was established for wheat flour. This followed numerous meetings by such groups as the American Medical Association and the Committee on Foods and Nutrition of the National Research Council (later to be named the Food and Nutrition Board) and hearings by the Food & Drug Administration.

These standards were amended in 1943 and are currently the standards of identity in effect,* requiring the addition of thiamin, niacin, riboflavin, and iron if wheat flour is to be labeled as enriched. There is also the option of adding calcium and vitamin D. Enrichment of bread was also inaugurated in 1941 even though the official standards of identity were not established until much later; in fact, it was in 1952 that they were finally officially established.

The Federal regulations concerning enrichment do not require the mandatory addition of these nurtients to flour and bread but provide that these standards must be met if the products are to be labeled enriched. Many States passed mandatory enrichment laws, with 34 States today having such requirements.

The principles of enrichment were expanded to corn products (grits, meal, and flour), rice, and pasta products, although riboflavin addition to rice has not been required due to the color problem. For those who are interested in a detailed history of the development of cereal grain enrichment, I recommend reading Bulletin No. 110 of the National Research Council, entitled "Enrichment of Flour and Bread--A History of the Movement."

The standards of identity for enrichment of cereal products established in this period are still the regulations governing cereal grain enrichment today. In 1971 a Subcommittee of the Food and Nutrition Board was established to review cereal grain enrichment to determine if changes should be recommended in light of newer information. A report has been submitted in this calender year which is currently under review by the National Academy of Sciences, and in accordance with Academy policy its content cannot be released until final approval by the reviewing authorities. Therefore, today I shall discuss some of the aspects of cereal grain enrichment which I think are likely characteristics of future programs. This should not be construed as outlining the specific programs which may result from the National Academy of Sciences report.

First, let's consider if current enrichment programs have been successful. After all, if we are to continue or consider changing these programs, we should review the contribution current programs have made to the nutrition of the American people. It is difficult to make a clear-cut assessment, as there have been many changes over the past 30 years in food technology and marketing techniques that have led to the introduction of totally new foods in the U.S. diet. The consumption patterns have changed in many households, with traditional meal patterns frequently replaced in part at least by increased consumption of snack foods. Total caloric requirements have declined as mechanization and improved transportation systems reduced the physical expenditure required for many occupations. Large numbers of people are weight conscious and dieting in various degrees, thus further restricting caloric intake and the consumption of foods that had been traditional sources of many nutrients. Consequently, data that were used in developing the enrichment pattern established in the 1940's may no longer be valid.

In assessing the success of the current enrichment program, it is apparent that many of the manifestations associated with the frank nutritional deficiencies that led to the development of the current programs have disappeared. Also, an ARS report (1) concluded that enrichment and fortification supplemented the nutrients in the 1970 food supply by 40 percent in the case of thiamin; iron, 25 percent; niacin, 20 percent; and riboflavin, 15 percent. Significant amounts of other vitamins were also provided through food fortification but at a lesser contribution than those listed above. Likewise, Howard (2), summarized data showing that the maintenance of intake of thiamin, riboflavin, niacin, and iron in the face of declining consumption of cereals and baked goods since 1940 was clearly due to the contribution of cereal enrichment programs.

---

*New standards were announced October 15, 1973, with mandatory compliance set for April 15, 1974. Levels of iron, thiamine, riboflavin and niacin were raised among other changes. February 11, 1974, the FDA announced changes; the deadline for compliance with the new enrichment standards for thiamin, riboflavin and niacin was deferred to January 1, 1975; the deadline with respect to higher iron levels was delayed indefinitely to permit a public hearing on the public health aspects. The Editor.

The Food and Nutrition Board of the National Academy of Sciences has just published a new policy statement (3) which, in part, states that specifically the following practices in the United States continue to be endorsed:

> "The enrichment of flour, bread, degerminated corn meal, corn grits, whole grain corn meal, white rice, and certain other cereal grain products with thiamin, riboflavin, niacin, and iron; -- "

It is reasonable to ask, in view of the changes in food consumption patterns, whether cereal grain products are still an appropriate vehicle for supplementing nutrient intake in our diets. I believe the following criteria should be considered when assessing the suitability of a food source as a carrier of supplemental nutrients:

1. The food source should be relatively economical so as to be within the purchasing power of the majority of the population and broadly consumed by all groups of the population and in particular by those groups shown to be at the greatest nutritional risk.

2. The food source should permit fortification at relatively low levels and yet provide a significant level of added nutrients at normal rates of consumption.

3. The range of consumption of food sources by various segments of the population should be reasonably well defined and not so broad as to provide only insignificant nutritional intake of the added nutrients at the lower range of consumption or to risk excessive intake at the upper range of consumption of any of the added nutrients to the point of potential toxicity.

4. Uniform distribution of the added nutrients in the carrier should be possible, and problems of segregation as the food source moves through the distribution channel should be minimal.

5. The food source should not contribute to instability of the nutrients added nor interfere with the utilization of these nutrients.

Of all of the major classes of foods consumed in the United States, cereal grain products--that is, food products derived from wheat, corn, oats, and rice--appear best to meet the criteria established for multiple fortification, and meet all of the criteria for a number of nutrients.

The contribution that cereal grain products make to the total caloric intake of individuals in the United States and the wide distribution of their consumption by all age groups was clearly shown in the U.S. Department of Agriculture 1965-66 Household Food Consumption Survey. The report (4) covers a nationwide survey in the Spring of 1965 of food intake, based on 24-hour recall, that sampled representative groups of men, women, and children covering a total of 14,500 individuals. The data showed that cereal grain products provided at least 25 percent of the calories consumed in a day, with approximately 17 percent of the calories consumed coming from the cereal grain itself. This is based on converting cereal grain products to a flour equivalent. Also, 99 percent of the people surveyed consumed a cereal grain product during the period.

It is recognized that there are regional differences in cereal grain product consumption. People in some regions, in part due to predominance of certain ethnic groups, follow dietary patterns that emphasize the use of certain cereal grain products. In addition, regional income differences may influence the amount of cereal grain products included in the diet. However, an examination of the data from this same USDA 1965 Household Food Consumption Survey on a regional basis reveals that the differences are not great between regions and not of the magnitude that would render cereal grain products unsuitable for carrying necessary nutrients. The southern region had the highest percentage of total caloric intake from grains, averaging 18.6 percent; all other regions averaged 15.8 percent of their caloric intake from grains on a flour equivalent basis.

Likewise, this same survey revealed that, on an income basis, those individuals with income under \$3,000 averaged approximately 21 percent of their total calories from grains, whereas the highest income level (those in the \$8,000 per year and over) averaged approximately 15 percent of their total caloric intake from grains, again expressed on a flour equivalent basis. This range of consumption is not so large as to make cereal grain products unsuitable as a carrier for nutrients added through fortification programs.

Past experience has shown, with the limited number of nutrients used in enriching cereal grain products, that relatively few problems with segregation have occurred with packaged products. There are, however, few data available regarding the segregation of nutrients that may occur in bulk shipments and pneumatic handling systems. If nutrient fortification programs are expanded to include additional nutrients, studies will be necessary to determine whether segregation of these nutrients will occur, and methods of adding nutrients may have to be developed which will permit the use of economical bulk distribution systems without nutrient segregation.

The nutrients currently used in cereal enrichment programs--that is, iron, thiamin, riboflavin, and niacin--are quite stable as they are used. If the nutrients have been added in a biologically available form, they have been available from the finished food product. Considerable research is now going on to determine the availability of various iron sources and the best iron source to be used for a particular enrichment program. Again, if additional nutrients are considered for fortification of cereal grain products, it will be necessary to obtain data to assure that the added nutrients remain stable and are available from the products.

One of the real advantages in using cereal grain products as a basis for enrichment programs has been the ability to obtain widespread consumption of these nutrients without changing food consumption patterns. If added nutrients in the fortification program result in reduced acceptance of products, then the purpose of the added fortification would be defeated. Therefore, any new fortification programs would require studies to determine that there were no adverse effects on consumption.

Let's now consider the question as to whether there should be a change in the various nutrients and/or the levels of nutrients used in cereal grain enrichment programs. In December 1971 the Commissioner of Food & Drug Administration recommended the trebling of the levels of iron in flour and bread enrichment. This recommendation has the endorsement of the Food and Nutrition Board of the National Academy of Sciences and the Council on Foods and Nutrition of the American Medical Association. This proposal has not as yet been finalized, primarily due to the concern expressed by some individuals to the increased iron levels.

When deciding whether additional nutrients should be added in a cereal enrichment program the intake of the various nutrients relative to the Recommended Dietary Allowances established by the Food and Nutrition Board should be considered. While it is desirable to meet nutritional needs by the use of an adequate amount and variety of foods, this is not always accomplished. With the broad variety of foods available today, the consumer has the opportunity to select a wide range of foods that can result in many patterns of nutrient intake. This makes it difficult to assess clearly the nutritional status of individuals. Therefore it is difficult to obtain clear-cut information to determine whether significant numbers of our population are consuming diets marginal in one or more essential nutrients. While the ideal situation would be to have well-documented clinical evaluations based on extensive biochemical studies, using criteria for judging nutritional adequacy that have been carefully evaluated, such data are not available and are highly unlikely to be available in the near future. Therefore, in selecting nutrients for inclusion in a fortification program, judgments must be based on the best information available with a view toward adequately meeting the nutritional needs of those groups of the U.S. population that appear to be at the greatest nutritional risk.

The 1965 USDA survey of food intake of individuals is useful in assessing the adequacy of nutrient intake of segments of the U.S. population relative to Recommended Dietary Allowances. This survey revealed that several individuals were consuming calcium, iron, thiamin, riboflavin, vitamin A, ascorbic acid, B_6, and magnesium at levels frequently considerably below the recommended allowances for the sex and/or age groups involved. In 1968 the Department of Health, Education and Welfare launched the Ten-State Nutrition Survey for the purpose of determining the nutritional status of individuals, with particular emphasis to those in lower income census groups. The dietary information obtained from this survey indicated that significant numbers of individuals had intakes below the recommended dietary allowances for calcium, iron, and vitamin A. Biochemical tests also provided evidence that nutritional iron deficiency existed in essentially all population groups studied. The biochemical data also revealed that several segments of the population groups surveyed showed evidence of inadequate values for vitamin A, riboflavin, thiamin, and vitamin C.

There have been numerous workshops dealing with various nutrients of concern and other publications which have provided useful information on the nutritional status of the U.S. population.

Recent research reported by Hambidge et al. (5) revealed the presence of apparent zinc deficiency in children from middle and upper socio-economic families in Denver. Thus zinc deficiency, which has been observed in severe form in Irani and Egyptian adolescents, has apparently been confirmed as appearing in the U.S. Zinc addition to the diets of swine and poultry in the U.S. has been practiced for many years. Current recommended dietary allowances do not include a recommended intake for zinc. This likely will be modified in the RDA's that are currently under revision.

Several nutritionists have been concerned with the possibility of a folate deficiency. There is considerable evidence in the literature indicating that the average dietary intake may be marginal in folacin, and cases of folate deficiency have been recognized in the population. However, the lack of substantive data on food consumption and the lack of suitable folacin assay methods have made assessment of the consumption of folacin relative to estimated requirements difficult.

In summary, it appears from the various sources reviewed that some degree of nutritional risk exists, at least for some groups in our population, for the following nutrients: vitamin A, vitamin C, thaimin, riboflavin, niacin, vitamin B_6, folic acid, iron, calcium, magnesium, and zinc. Current enrichment programs essentially deal only with thiamin, riboflavin, niacin, and iron. Thus it appears that future programs should consider a broader addition of nutrients.

In defining what I believe to be the characteristics of future enrichment programs, the following appear to be pertinent:

1. Future enrichment programs should be based on enriching the major cereals--that is, wheat, corn, and rice--on a common basis. This would permit the interchange of one cereal for another without reducing the impact on nutrient intake from these sources.

2. Enrichment of the basic cereals at the point of initial processing, for example flour milling, would permit the broadest inclusion of enriched cereals in food products based on cereal grains.

3. Any future enrichment programs must not adversely influence acceptance of the products, as this would be counterproductive in improving nutrient intake.

4. Milling programs should be developed which will minimize loss of the native nutrient content of the cereal grain consistent with providing a cereal product that has the necessary functionality and consumer acceptance characteristics.

If such a program were to be adopted, what demands might be made on the cereal milling industry? I foresee the need for:

1. Considerable research on the technology of enrichment of various cereal products to determine whether it is feasible to add the various nutrients without adversely affecting acceptance of the final product.

2. The development of technology, where it is not available, that would permit the enrichment being carried out at the point of manufacture of the basic cereal flour so as to obtain the broadest distribution of enrichment in products based on cereal grains. In view of current and future extensive use of bulk handling and pneumatic conveying systems, it would be essential to determine whether the technology of enrichment would prevent segregation or loss of added nutrients in the distribution system.

3. Research would be required to determine the stability and availability of the nutrients from the cereal grain product and any effect that may be had on product stability as the result of adding additional nutrients.

4. Research in milling technology and also at the consumer level to determine if milling practices can be changed which would result in increasing the retention of nutrients naturally present in cereal grains, particularly the various trace elements, and likewise whether the use of various bleaching and/or maturing agents, which in some instances adversely affect retention of nutrients, are required.

In closing, I think it is essential that indiscriminate addition of nutrients to foods be avoided. The Food and Nutrition Board 1973 statement of policy concerning the nutrient addition to foods is a sound guide for industry to follow in deciding on food product fortification. Cereal grain products, due to their broad use in the diet, their suitability as a carrier, and their relative economy, are a logical food source to serve as the carrier for most nutrients for which there appears to be a nutritional risk in our population. Our challenge is to reach agreement on which nutrients should be provided in enrichment programs in accordance with the potential nutritional risk that exists in our population and to develop the necessary technology which will permit carrying out such a program in the most expeditious manner for all concerned.

Literature Cited

1. Friend, B. Enrichment and fortification of foods, 1966-1970. National Food Situation (NFS-142), pp. 29-33, Nov. 1972.

2. Howard, H. W. Opportunities in enrichment. Cereal Sci. Today 11(6): 244-46, 1966.

3. Food and Nutrition Board, NRC, NAS. General policies in regard to improvement of nutritive quality of foods. NAS policy statement, 1973.

4. Consumer and Food Economics Res. Div., ARS, USDA. Household Food Consumption Survey, 1965-1966. Report No. 11: Food and nutrient intake of individuals in the United States, Spring 1965. Issued Jan. 1972.

5. Hambidge, K. M., Hambidge, C., Franklin, M. F., and Baum, D. Zinc deficiency in children manifested by poor appetite and growth, impaired taste acuity, and low hair zinc levels. Amer. J. Clin. Nutr. 25(4:) 453-454, 1972.

NUTRITIONAL LABELING, WHEAT, AND THE NUTRIENT DATA BANK

Robert L. Rizek
Consumer and Food Economics Institute
Agricultural Research Service, U.S. Department of Agriculture

This paper outlines the general objectives and protocol of the voluntary nutritional labeling program of the Food and Drug Administration and it's relation to the Nutrient Data Bank (NDB) of the Agricultural Research Service, with emphasis on their relationship to wheat and wheat products. Also outlined are the data needs of the NDB relative to the increased number of wheat products and changing methods of manufacturing.

Over the next few months and years there will be significant changes in the information presented on the labels of the foods purchased at local supermarkets. These changes are a result of a Food and Drug Administration program to make food labeling more informative as an aid to better nutrition. This program, as published in the Federal Register, March 14, 1973 (1), is designed to provide information that consumers can use to identify and select nutritious foods.

The nutritional labeling program has essentially two purposes:

1. To make more nutritional information available on food labels. This will be accomplished primarily by a voluntary program with industry which calls for the listing of nutrients in a standard format.

2. To make information on food labels more meaningful to the public. This will be accomplished in part by setting standards for identifying essential vitamins and minerals and in part by a change in the system of measuring nutritional intake. The new measurement is based on "recommended" daily allowances of nutrients as contrasted with "minimum" nutritional needs.

The nutritional labeling program has raised a number of questions with the wheat industry and others, as it well should, on what impact it will have on marketing, the importance of and problems associated with defining serving or portion sizes, handling of normal nutrient variations, the use of representative nutrient composition data, analytical methods, and the nutrient data bank. However, before discussing these various questions a summary of the nutritional labeling program is needed.

Nutritional Labeling. The voluntary nutritional labeling regulation governs when and how food labels will contain information about the nutritional content of foods. Whenever a food is labeled with nutrition information, the FDA requires that the label must follow this standard format: Nutrition information per serving. 1. Serving size, 2. Servings per container, 3. Caloric content or calories, 4. Protein content or protein (grams), 5. Carbohydrate content or carbohydrates (grams), 6. Fat content or fat (grams) and 7. Percentage of U.S. Recommended Daily Allowances (U.S. RDA) for protein, seven vitamins and minerals required to be listed and twelve additional vitamins and minerals that may be listed.

For most foods, nutritional labeling is voluntary. However, if a nutrient is added, even to replace those lost in processing, or if a nutritional claim is made for an item, either in an advertisement or in the labeling, the product must have full nutritional labeling. Examples of products that are normally sold as "enriched" or "fortified" and thus requiring full nutritional labeling are enriched flour, enriched bread and other baking products, enriched pasta, and breakfast cereals with nutrients added. If an ad or label makes any reference to protein, fat, carbohydrates, calories, vitamins, minerals, or use in dieting, complete nutrition information must be contained in the label.

On the food labels, the levels of vitamins and minerals will be listed as a percentage of the U.S. Recommended Daily Allowances (U.S. RDA).

Currently, the labels of cereal boxes have listed nutrients as the "percentage of MDR." This is the old Minimum Daily Requirement, established by FDA in 1941. It has been out of date for several years and doesn't list several vitamins and minerals that are of concern today. The new standard (U.S. RDA) is based on the Recommended Dietary Allowances of the National Academy of Science-Food Nutrition Board. FDA received many recommendations on the form of the RDA that should be used. The U.S. RDA finally selected for most nutrients was the highest RDA for any of the sex-age categories for which allowances are set. The exceptions are calcium and phosphorus.

If nutritional labeling is used, values for food energy, protein, carbohydrate, fat, and at least seven vitamins and minerals must be shown on the label. These are vitamin A, vitamin C, thiamin, riboflavin, niacin, calcium, and iron. In addition, 12 other vitamins and minerals may be listed. Included are vitamins D, E, B-6, B-12, folic acid, phosphorus, iodine, magnesium, zinc, copper, biotin, and pantothenic acid.

An example of a typical format of nutrition information is shown in Figure 1. Values on this label are for a 1-cup serving of the food in the container. This container provides two such servings.

NUTRITION INFORMATION

(Per Serving)

Serving Size = 1 cup — Servings Per Container = 2

Calories	40
Protein	2 grams
Carbohydrate	7 grams
Fat	0 grams

Percentage of U.S. Recommended Daily Allowances (U.S. RDA)

Protein	2
Vitamin A	10
Vitamin C	8
Thiamin	2
Riboflavin	4
Niacin	2
Calcium	6
Iron	10

Figure 1. Typical nutritional label.

Food energy in calories, and protein, carbohydrate and fat in grams are shown first; then the percents of the U.S. RDA for protein and the five vitamins and two minerals required.

Figure 2 is a label for muffin mix—a food that is combined with other foods before it is eaten. This label is similar to the first one except that a second column of values has been added. The second column shows values for the mix plus ingredients that are added by the homemaker as the food is prepared. Values for the food as it comes from the container (column 1) must be included if nutrition information is given. The double listing, including value of the food as eaten, may be used only when specific use instructions are given.

NUTRITION INFORMATION

(Per Serving)

Serving Size = 1 muffin — Servings Per Container = 12

	Mix	Mix + 1 Egg + 1/2 c. milk
Calories	120	130
Protein, grams	2	3
Carbohydrate, grams	20	20
Fat, grams	3	4

Percentage of U.S. Recommended Daily Allowances (U.S. RDA)

Protein	2	4
Vitamin A	0	2
Vitamin C	0	0
Thiamin	4	4
Riboflavin	2	4
Niacin	2	2
Calcium	8	10
Iron	2	4

Figure 2. Nutritional label for muffin mix.

Under certain conditions a slightly simplified version of the label can be used. An example is shown in Figure 3. If only three of the eight nutrients--protein, vitamins, and minerals, are present in amounts equal to or greater than 2 percent of the U.S. RDA, only these need be listed. However, a note indicating that the food contains less than 2 percent of the U.S. RDA's for the remaining nutrients, as shown in Figure 3, is required.

NUTRITION INFORMATION

(Per Serving)

Serving Size = 1 oz.

Servings Per Container = 12

Calories	110
Protein	2 grams
Carbohydrate	24 grams
Fat	0 grams

Percentage of U.S. Recommended Daily

Allowances (U.S. RDA)*

Protein	2
Thiamin	8
Niacin	2

*Contains less than 2 percent of U.S. RDA for Vitamin A, Vitamin C, riboflavin, calcium and iron.

Figure 3. Simplified nutritional label where only three nutrients are present in significant amounts.

In addition to the regular format for nutritional labeling, provisions have been made for showing the amount of cholesterol and saturated and polyunsaturated fats per serving. This allows consumers to identify foods for inclusion in physician recommended fat-modified diets. Figure 4 illustrates how the

NUTRITION INFORMATION

(Per Serving)

Serving Size = 8 oz.

Servings Per Container = 1

Calories	560
Protein	23 gm
Carbohydrate	43 gm
Fat (Percent of calories 53%)	33 gm
Polyunsaturated*	2 gm
Saturated	9 gm
Cholesterol* (20mg/100 gm)	40 mg
Sodium (365 mg/100 gm)	830 mg

Percentage of U.S. Recommended Daily

Allowances (U.S. RDA)

Protein	35
Vitamin A	35
Vitamin C (ascorbic acid)	10
Thiamin	15
Riboflavin	15
Niacin	25
Calcium	2
Iron	25

*Information on fat and cholesterol content is provided for individuals who, on the advice of a physician are modifying their total dietary intake of fat and cholesterol.

Figure 4. Nutritional label with cholesterol and fat information.

optional forms of labeling--cholesterol and fat composition--can be used and combined with nutritional labeling. If this type of labeling is used, in the line for fat a parenthetical expression should describe the percent of calories from fat. For example, "percent of calories from fat equals 53 percent." This then would be followed by the number of grams of fat just as in the usual nutrition label. Immediately, below this would be a statement "saturated," listing the number of grams of saturated fat per serving.

If fat labeling is used, it should be followed immediately by "Cholesterol" in milligrams per serving and milligrams per hundred grams. If the manufacturer wishes, this can be followed by a statement of sodium content milligrams per 100 grams and per serving. Whenever fat description and/or cholesterol are listed, the declaratory statement must be made, "Information on fat and cholesterol content is provided for individuals who on advice of a physician are modifying their total dietary intake of fat and cholesterol."

Compliance. It is widely recognized that there is natural variation in the nutrient content of food products. This variation may be related to many factors--such as variety, location of production, and weather. As a product is processed, further variation may occur as a result of differences in processing techniques and limited quality control.

The FDA realizes the importance of permitting sufficient tolerance to allow manufacturers to provide useful nutrition information without excessive costs. However, consumers have a right to expect the labels to present reliable information about the foods they buy. Compliance procedures were developed after consideration of problems of both the manufacturer and the consumer.

The procedures adopted allow for little fluctuation in nutrients that are added to food (Class I nutrients). For these, the nutrient level in any one lot is required to meet the label value. For those nutrients that are naturally occuring in foods (Class II nutrients),such as vitamins A and C in tomatoes, the regulation permits considerably more fluctuation. The nutrient level in any one lot must be at least 80 percent of the labeled value. The regulation goes on to state that a standard deviation of 10 percent might be expected for Class I nutrients and 25 percent for Class II nutrients. Additional information (2) is available from the FDA.

Wheat and Nutritional Labeling. To those involved in any industry an immediate concern arising from a program such as nutritional labeling is how the program will affect them in terms of demand and costs. Although the use of nutritional labeling will result in added problems for the wheat industry, as well as for others, it appears that nutritional labeling also could benefit the industry as well as consumers who use wheat products.

Cereal grains and their products have long been recognized for their contribution to the nutrition of the nation. The USDA includes cereal grain products prominently in its guides to good food selection for consumers. The Daily Food Guide features bread and cereal as one of the four major food groups. We currently have in preparation, guidance materials for consumers which, along with the Daily Food Guide, will assist them in utilizing nutritional labeling.

The USDA food plans at different cost levels all include substantial amounts of flour, cereals, and bakery products. Because these products provide many nutrients economically, larger quanitites are suggested in the low cost than in the more expensive plans.

Grain products are a part of the patterns for type A school lunches and for school breakfasts. Grain products must be included in school meals that qualify for Federal assistance. Grain products are also included in the food distributed by the USDA to needy families and institutions under the Commodity Distribution Program.

Wheat products make significant nutrient contributions to U.S. diets as shown in Table 1. Not only do wheat products supply significant quantities of the nutrients required for an adequate diet, they do so quite economically. In the last USDA food consumption survey (1965), selections of grain products accounted for 12 percent of the total money value of food used by U.S. households. This 12 cents of every dollar, however, furnished 40 percent of the thiamin in diets of U.S. households, 31 percent of the iron, 26 percent of the food energy (calories), 20 percent of the protein, 19 percent of the riboflavin, and 17 percent of the calcium. The listed percentages indicate total nutritive value of the foods classed as grain products, not just wheat products. Some of the nutrients were provided by ingredients other then grains in bakery products, i.e., some of the protein, riboflavin, and calcium were provided by milk, etc. In addition, some of the nutrient contribution resulted from enrichment and fortification.

Presumably nutrition information on labels will draw attention to those cereal products that make major contributions of nutrients. The potential impact of this type of labeling on the consumer's uses of foods is probably best understood by cereal manufacturers who have marketed foods labeled with nutri-

Table 1.--Contribution of wheat to nutrient supplies. Based on U.S. per capita food disappearance for 1972

Nutrients	With Enrichment and Fortification	Without Enrichment and Fortification
	Percent	Percent
Food Energy (Calories)	15.5	15.5
Protein	14.8	14.8
Fat	0.9	0.9
Carbohydrate	28.0	28.0
Calcium	2.6	2.6
Phosphorus	9.0	9.0
Iron	20.6	8.1
Magnesium	11.8	11.8
Thiamin	27.9	6.7
Riboflavin	13.8	3.3
Niacin	19.1	7.2
Vitamin B_6	5.2	4.1
Vitamin B_{12}	0.8	0.0

tion information for years. Indeed, many consumers will recognize the words "protein," "thiamin," and "riboflavin" as nutrients only through their breakfast table reading of cereal boxes.

Labeling of a wide variety of foods adds new dimensions to consumer use of nutrition information. To what extent such information will be useful to consumers in selecting a nutritionally good diet is not yet known. Ways the consumer may use the information can, however, be anticipated. First, the consumer who reads and tries to understand labels will become aware of some of the nutrients required for growth and health. He may learn that foods vary in the kinds and amounts of nutrients they contain and that a variety of foods is required to supply the U.S. RDA. He could learn which foods of those that have nutrition labels are high in calories and which are worthwhile sources of certain nutrients. But the consumer will need additional information and guidance if he is to make meaningful comparisons among foods and evaluations of his day's food by using labels.

The most meaningful comparisons for consumers using nutritional labeling will be those made among foods that might be substituted for each other in meals. For example, values for whole wheat bread might be compared with those for white bread; values for toast, with those for English muffin; those for cereal with those for egg, etc. To compare values of one type of food with those of another--bread and tomato juice for example--is not altogether helpful. Bread is counted on for certain nutrients, and tomato juice is counted on mainly for others. In addition, these foods are not normally substituted for each other. Even if comparisons such as these are made between wheat products and other types of foods, many wheat products, as exemplified by bread and ready-to-eat cereals, will compare quite favorably with those in other food groups (Table 2).

Factors such as these illustrate that wheat provides a significant amount of the nutrients required by each of us, and at a reasonable cost. It would appear that the wheat industry, using facts such as these in conjunction with nutritional labeling, could further the use of wheat. Especially now, when consumers seem to have increased concern about nutrition, nutritional labeling provides you with the means to promote the excellent qualities of wheat.

Serving and Portion Sizes. In nutritional labeling, all nutrient quantities must be declared in relation to an average or usual serving, or, where the food is not consumed directly, in relation to the average or usual portion. Another column may be used to declare the nutrient quantities in relation to the stated average or usual amount consumed on a daily basis. For example, the quantity for bread might be 2 slices as a usual serving and 6 slices as an average amount consumed in a day (Figure 5).

The setting of standard serving sizes would be helpful for both consumers and industry. It is important that serving sizes be selected that are appropriate in relation to common use of the food and that a given food be described in terms of only a single serving size by all manufacturers. The FDA has indicated that it may take steps to insure that uniform standard sizes are selected if necessary. It would be unfortunate if companies within an industry were to enter into a "horsepower race" by increasing serving sizes through time to make their product look better nutritionally. Not only would it result in increased costs by a continual change of labels, but it also would be highly confusing for consumers.

Table 2.--Food energy and percentage of U.S. RDA for eight nutrients provided by a serving of selected food 1/

Food 2/	Size of Serving (ready-to-eat)	Food Energy	Protein	Vit. A	Vit. C	B-vitamins			Ca	Fe
						B_1	B_2	Niacin		
		Calories	%	%	%	%	%	%	%	%
Whole Wheat Bread	2 slices	110	8	*	0	10	2	6	4	6
....	6 slices	340	25	*	0	30	8	20	15	20
White Bread	2 slices	130	6	*	0	10	4	8	6	8
....	6 slices	400	20	*	0	35	10	25	20	25
English Muffin	1 muffin	140	6	*	0	10	8	8	10	6
Cereal, ready-to-eat 3/	1 ounce	110	4	20	20	25	25	20	*	20
Puffed Wheat	1 ounce	100	6	0	0	10	4	10	*	6
Wheat Flakes	1 ounce	100	4	25	15	20	25	15	2	10
Bran Flakes	1 ounce	90	4	25	15	20	25	15	2	60
Shredded Wheat, Added Malt and Sugar	1 ounce	100	4	25	15	20	25	15	2	60
Milk, Whole Fluid	1 cup	160	20	6	4	4	25	*	30	*
Cheese,Process Cheddar	1 ounce	110	15	6	0	*	8	*	20	*
Meat, Poultry, Fish (lean)	3 ounces	220	50	15	*	10	15	25	*	15
Eggs	1 large	80	15	10	0	4	8	*	2	6
Citrus Juice	1/2 cup	60	*	6	100	8	*	2	*	*
Tomatoes, Tomato Juice	1/2 cup	25	*	20	35	4	2	4	*	4
Dark-green and Deep-yellow Vegetables	1/2 cup	45	4	140	40	6	6	4	6	6
Potatoes	Medium	80	4	--	35	8	2	6	--	4
Other Vegetables	1/2 cup	45	4	8	20	4	4	2	2	4

1/ Percentages expressed in increments as required by regulation (1) for nutrition labeling: 2-percent increments up to and including 10-percent level; 5-percent increments above 10 percent and up to and including the 50-percent level, and 10-percent increments above the 50-percent level.

2/ "Nutritive Value of Foods," USDA, HG-72, was used as a basis for percentages for most foods. Values for food groups are based on average selections of foods in the group by U.S. families.

3/ Based on average of values on labels of 59 varieties of ready-to-eat cereals, February 1973.

*Some but less than 2 percent of the U.S. RDA.

NUTRITION INFORMATION

(Per Serving)

Serving Size = 2 Slices or 6 Slices

Servings per Container = 9 or 3

	2 slices	6 slices
Calories	130	400
Protein, Grams	4	12
Carbohydrate, Grams	25	76
Fat, Grams	1	4

PERCENTAGE OF U.S. RECOMMENDED DAILY

ALLOWANCES (U.S. RDA)

	2 slices	6 slices
Protein	6	20
Vitamin A	*	*
Vitamin C	0	0
Thiamin	10	35
Riboflavin	4	10
Niacin	8	25
Calcium	6	20
Iron	8	25
Pantothenic Acid	*	2
Vitamin B_6	0	0
Vitamin B_{12}	*	2
Phosphorus	10	25

*Contains less than 2 percent of the U.S. RDA of these nutrients

Figure 5. Nutritional label for white bread giving required data for per serving (2 slices) basis and optional data for per day (6 slices) basis.

Several groups wanted the FDA to establish serving sizes. The FDA Commissioner, however, decided that this was not reasonable and that it would be far better if trade groups and their members would establish serving sizes and portions among themselves. The American Home Economics Association, at the request of several industry groups, is developing standard serving sizes. To assist this committee of AHEA, CFEI is providing to them the average serving sizes obtained from our 1965 food consumption survey.

The establishment of standard serving sizes will not entirely relieve all problems--to realize this one only has to look at the sizes and shapes of loaves of bread as well as the thickness of the slices. The FDA is not insisting, of course, on one size and shape of a loaf of bread. Consumers, however, will have to recognize that two thin slices of bread could not be expected to provide the same quantity of nutrients as could two thick slices.

Nutrient Data Bank. The FDA has indicated that representative data presently available from such sources as USDA Handbook 8 (3) are not sufficient to be a basis for nutritional labeling. For each product, it is essential that representative data be checked by analysis of individual lots at least until more complete food composition data are available on an industry wide, regional, and manufacturing basis. At some point in the future, use of the Nutrient Data Bank, backed up by periodic analytical spot checks, will undoubtedly be possible in achieving FDA compliance.

A use of AH-8 (Handbook 8), which until recently has been overlooked, is that of determining those nutrients in a product unlikely to have labelable amounts. Review of representative data for a specific product may indicate that only two or three nutrients may be expected to reach 2 percent or more of the U.S. RDA. A profile analysis for all the nutrients would not be necessary and under these circumstances a food company could request analyses only for those nutrients that might be present at two percent or more of the U.S. RDA.

It was because of this, plus the fact that there is an urgent need by nutritionists, dietitians, and doctors for more complete food composition data, that members of the USDA began meeting approximately 2 years ago with industry, the FDA, and others to develop plans for the Nutrient Data Bank (NDB).

Considerable progress has been made in the development of the NDB. A format was developed and pretested for submitting data for the bank and updating previously submitted data, and has since been sent to participating trade associations, companies, universities and independent laboratories. Considerable work has been done on a coding system that will identify foods and be useful for data retrieval, but the work is not yet completed.

The data available from the computer data bank will be somewhat different from the data now available in USDA food composition publications. The Nutrient Data Bank, when fully operational will make available not only the nationwide representative composite values for the various nutrients found in a specific food, but also the standard errors of the values whenever feasible. Also available will be the individual analytical values submitted for the different foods. Where sufficient data are available, representative composite values and standard errors will be developed by variety, stage of maturity, season and geographic location.

One immediate and direct utilization of the NDB will be the publication of the next edition of AH-8. Except for the change in form--it will be published in looseleaf form--and an expansion in the number of foods and nutrients covered, the revision of AH-8 will continue primarily as it has in the past--giving representative nationwide values for the nutrients in foods. In addition to the representative nationwide values, the edition will include, whenever practical, the standard errors of the overall composite values and the composite values and standard errors by variety, stage of maturity, etc.

The form developed for data submission is divided into two general sections. One is for providing a detailed description of the sample analyzed and other information needed to evaluate and code the data. The other section is for posting of data on approximately 100 nutrients and related compounds in foods as well as for reporting analytical methods used in their analysis. Included are proximate components, minerals, fat soluble vitamins, water soluble vitamins, amino acids and lipids.

The form and data bank have been developed to cover all kinds of foods and components of those foods having nutritional importance. It is not expected that any one food will include values for all or even most of the nutrients specified.

Careful identification of the food sample is essential for evaluation of the data and for proper coding. Consequently, considerable information is required related to the description and identification of the food items. In addition to descriptive detail of the food item, a comprehensive checklist has been included to ease the task of describing the sample and to call attention to the kinds of information that can be given.

Information needed includes such things as the name of the food--generic and scientific--geographic location, target market for which the item was prepared, ingredients and directions for use, and any standards of compliance or identity which the product meets.

Product and processing information asked for includes treatments applied to the food, such as bleaching, curing, pickling; processing techniques--canning, freezing, dehydration, and milling; method of cooking; physical state of the food; portion of the food analyzed; and class, grade, variety or species.

In addition to the descriptive information about the food product and its nutrient contents, it is essential that the methods of sample preparation and analyses be provided. In most instances, these will probably be standard methods such as those of the Association of Official Analytical Chemists. In cases where AOAC method does not exist, the FDA has specified methods to be used in checking compliance. Several independent laboratories have listed what methods they find most reliable for various foods and/or nutrients.

As you all know the number and variety of wheat products on the market have mushroomed in recent years. Data for this ever-growing list of foods are needed for the NDB. Foods for which there is particular need for information are new varieties of wheat and their mill products; crackers, breads, rolls, and cakes of different types; macaroni products whereby semolina is mixed with flour or farina; extruded snack products; and fried pies, coffee cakes and filled doughnuts.

Of particular importance are detailed data on kind and amount of ingredients used in these products; for example, whole egg or egg yolk in noodles and the kind of fat in the formulation of wheat products. In addition, data are needed for the NDB on the fat used for frying such products as doughnuts, pies, and snack items and the uptake of the fat by these products.

In recent years some drastic and some subtle changes have occurred in the formulation of white bread. Following with the introduction of the continuous mix method of making bread, changes in the amount and kind of milk ingredients have been made that include the use of some whey, reconstructed milks and combinations of these with soy flour. Data are needed for current breads and roll products.

Treatments of air-classification, malting, phosphating, bolting, etc., could have a significant influence on nutritive values of cereal products and should be described when nutrient data are given.

Methods of cooking or baking should also be given since rate and extent of heat penetration have a bearing on vitamin retention.

Initial releases of the NDB will include the individual analytical values for each food which has been screened and appears to be acceptable. These data, in all likelihood, will be released by food groups in the following order: meat and meat products, cereals, dairy products, and fruits and vegetables, with data for the first group being made available within the next 2 years. The derivation of representative values which consumes considerable time, will be delayed until a large portion of the data are received, evaluated as to reliability, and made available through the computer data bank.

Representative values will be entered in the NDB by food groups in the order indicated, and will also be published in the successor of AH-8 which should follow shortly after being released in the data bank. However, the timing of release, as well as the order of release by food groups, will depend to some extent on the inflow of data in terms of quantity, quality, and speed.

Both the computer data bank and the successor of AH-8 will be updated on a continuing basis as new data are obtained for nutrients in the foods already included in the NDB or as industry develops new food products. In this way the user of either system will have the latest, most complete data that are available to the USDA.

The NDB will be available to anyone who may have need for this type of data. Although plans have not been finalized, the computer data tape probably will be made available for purchase through a private contractor, similar to the way the tape for Agriculture Handbook 8 is now handled. In addition, the software programs developed by the USDA for use in Departmental research programs will also be made available for those engaged in similar areas of research. The new edition of Agriculture Handbook No. 8 will be handled through the regular government publication process. A listing of those obtaining either of the two systems will be maintained so that they can receive any revised or new data as they are released.

Acknowledgment

The assistance of Betty Peterkin and Ruth Matthews in the preparation of this paper is gratefully acknowledged.

Literature Cited

1. Federal Register, Vol. 38, No. 49, Part II. Wednesday, March 14, 1973.
2. FDA, USDHEW. Compliance procedures for nutrition labeling. March 1973.
3. Watt, B. K. and A. L. Merrill. Composition of Foods. Agriculture Handbook No. 8, U.S. Department of Agriculture. 1963.

REMOVAL OF HEAVY METALS FROM WASTE WATER WITH A STARCH XANTHATE-CATIONIC POLYMER COMPLEX

R. E. Wing
Northern Regional Research Laboratory, Agricultural
Research Service, U.S. Department of Agriculture

Worldwide concern developed a few years ago when people became aware of the effect of discharging industrial effluents containing heavy metals into waterways. This led to the formation of a set of strict discharge limits for heavy metals that must be met before industrial effluents can be discharged. Several methods have been developed and are being used to treat these industrial effluents contaminated with heavy metals: 1. Chemical precipitation with lime, alum or iron salts, 2. Chemical treatment by oxidation or reduction, 3. Ion exchange, 4. Ultrafiltration, 5. Electro chemical, and 6. Evaporative recovery. Each of these methods have advantages but most have disadvantages requiring special modifications before use by certain industries.

The method developed at the Northern Regional Research Laboratory in Peoria offers industry a tool to remove heavy metals in most cases to concentrations below discharge limits.

NRRL Method to Remove Heavy Metals. Our method involves the sequential addition of starch xanthate and a cationic polymer [e.g., poly(vinylbenzyltrimethylammonium chloride) (PVBTMAC) or polyethylenimine (PEI)] to a heavy metal solution to precipitate both polymers and the heavy metals as a cohesive floc (Figure 1). Some of the xanthate groups on the starch backbone form heavy metal salts, while others react with the polycation to form an insoluble polyelectrolyte complex.

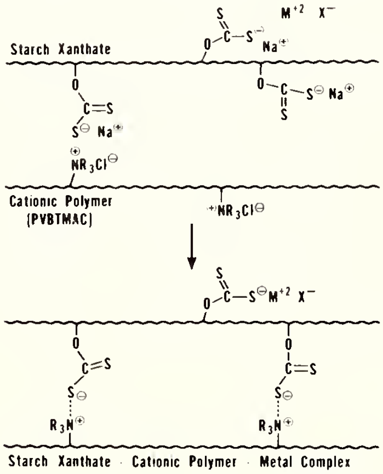

Starch Xanthate
M^{+2} X^-
Na^+
NR_3Cl^-
Cationic Polymer (PVBTMAC)
R_3N^+
Starch Xanthate · Cationic Polymer · Metal Complex

Figure 1. Starch Xanthate-cationic polymer-metal complex formation.

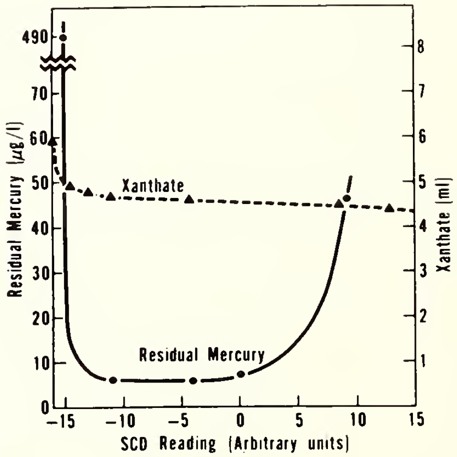


Figure 2. Relationships between volume of starch xanthate added, SCD reading and residual Hg concn. 50 ml samples containing Hg^{+2} (5 mg) and PVBTMAC (10 mg) were treated with starch xanthate [0.23 DS, 1% (w/v)].

The composition of the insoluble complex varies with the amounts of polymer added. In most cases the composition is 2:1:1 starch xanthate:cationic polymer:metal. This ratio suggests that a singly charged anion (Cl^-) is associated with a divalent metal ion.

The overall process involves precipitation, separation and recovery. Once the precipitate forms it settles rapidly and separation may be achieved by filtration, centrifugation or decantation. The resulting sludge can then be treated with acid or incinerated to recover the metal.

Variables Investigated. Several variables were evaluated to optimize heavy metal removal. Mercury was selected as the metal used in this evaluation; however, most heavy metals give similar results.

1. End-point determination. Solutions containing mercury and cationic polymer were titrated with 1% solutions of starch xanthate. The amount of xanthate required to give maximum precipitation of the cationic polymer and mercury was determined by streaming current measurements. Figure 2 shows how critical the amount of starch xanthate added is for the optimal removal of mercury. An excess of starch xanthate causes an imbalance between the polyelectrolytes and some mercury xanthate complex redissolves.

2. Concentration of cationic polymer. The optimum amount of cationic polymer was determined for various concentrations of mercury (Figure 3). From these data, for a 100 ppm solution of mercury, 0.46 g/1. PVBTMAC should be used to obtain a minimum residual mercury concentration.

3. Mercury concentration. Figure 4 shows how the initial mercury concentration effects the completeness of removal.

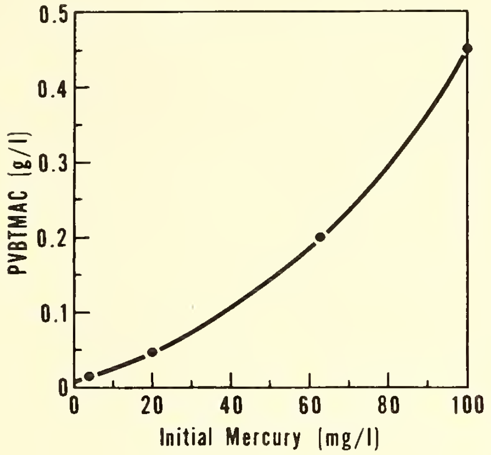


Figure 3. Relationship between initial Hg^{+2} concn. and dosage of PVBTMAC required for minimum residual Hg concn. Dosages of starch xanthate (0.23 DS) were [initial Hg concn. (mg/1), xanthate added (g/1)]: 4, 0.072; 20, 0.225; 63, 0.84; 100, 1.30.

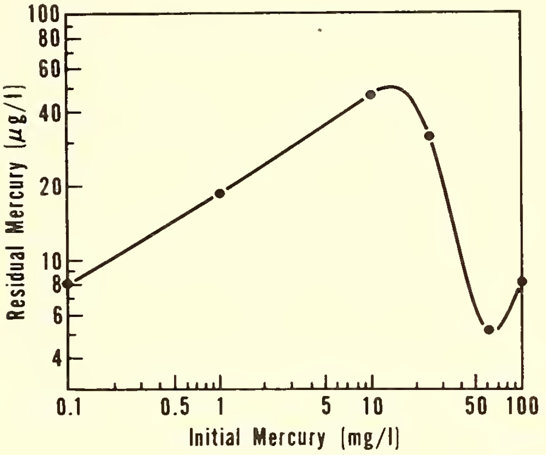


Figure 4. Effect of initial Hg^{+2} concn. on residual Hg concn. Dosage of PVBTMAC was 0.2 g/1. Dosages of starch xanthate (0.23 DS) were [initial Hg concn. (mg/1), xanthate added (g/1)]: 0.1, 0.623; 1,0, 0.630; 10, 0.655; 25, 0.680; 50, 0.758; 100, 1.006.

4. Rate of starch xanthate addition. Figure 5 shows that the slower the starch xanthate is added the more effectively it complexes with mercury.

5. Presence of salt. The method is effective if the salt (NaCl) concentration is below 3% (Figure 6).

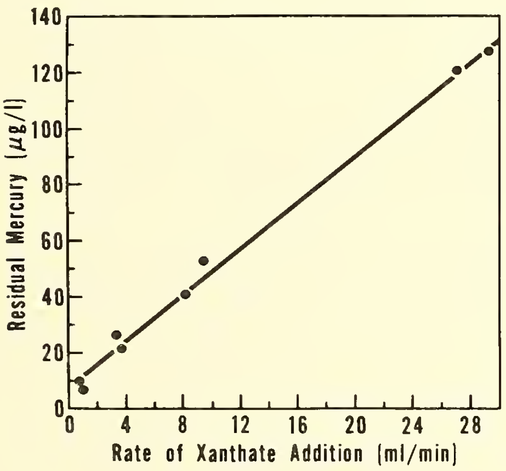


Figure 5. Rate of xanthate addition vs. residual Hg concn. 50 ml samples containing Hg^{+2} (100,000 μg/l) and polyethylenimine (0.2 g/l) were each treated with 8.12 ml of starch xanthate dispersion [0.12 DS, 1% (w/v)].

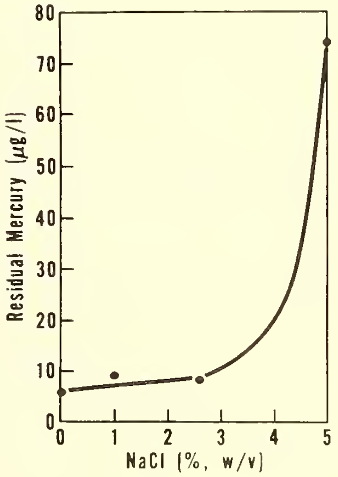


Figure 6. Effect of NaCl on residual Hg concn. Initial Hg concn. was 100,000 μg/l. Solutions were treated with PVBTMAC (0.2 g/l) and starch xanthate (0.23 DS). Dosages of xanthate were [salt concn. (%, w/v), xanthate added (g/l)]: 0, 0.926; 1, 0.68; 2.6, 0.64; and 5, 0.60.

6. Effect of initial pH. Treatment of mercury solutions having initial pH's of 3-11 result in low residual mercury concentrations. Solutions with pH's of less than 3 cause rapid decomposition of the starch xanthate.

7. Degree of substitution (DS) of starch xanthate. Starch xanthates having DS's from 0.11 to 0.40 were effective for removing mercury. Smaller addition volumes were required as the DS of the starch xanthate increased.

8. Order of addition of the polymers. The starch xanthate and cationic polymer can be added in either order for effective removal.

9. Omitting cationic polymer. Starch xanthate can react with mercury in the absence of cationic polymer to form a precipitate. However, this method was only effective for high mercury concentrations (100 mg/l.) and still left residual mercury above 100 µg/l.

10. Presence of sequestrants. The presences of selected sequestrants at the 0.1 grams/liter level does not affect removal of mercury (Table 1).

Table 1.--Effect of sequestrants on residual mercury level and starch xanthate requirement[1]

Sequestrant[2]	Residual Mercury µg/l	Xanthate Requirement meq X 10^2
Diglycolate	4.37	5.61
Nitrilotriacetic acid	3.86	5.19
Polyphosphate	10.30	3.36
Citrate	10.33	4.36
Control	6.10	6.53

---

[1] Meq of starch xanthate [1% w/v, 0.23 degree of substitution (DS)] required to precipitate 2.5 X 10^{-2} mM (5 mg) mercury (II) and 4.74 X 10^{-2} meq poly(vinylbenzyltrimethylammonium chloride) (PVBTMAC) from 50 ml of solution.

[2] In each 50-ml test solution 5 mg of sequestrant was used. The control contained none.

Residual Contaminants. Any process for removing heavy metals from water should not add other noxious substances. Contaminants that might be introduced by treatment of water with starch xanthate and a cationic polymer include: small ionic species (Cl^- from the cationic polymer; Na^+, OH^- and $CS_3^=$ from the xanthate), small nonionic species (CS_2 and COS from the xanthate), and the polyelectrolytes themselves. The residual concentrations found [chloride, 200 mg/l. and sulfur (reported as sulfate), 36 mg/l.] and the BOD_5 (0-12.5 mg/l.) were well below established limits. Therefore, precipitation of heavy metals with starch xanthate and cationic polyelectrolytes does not appear, in itself, to produce legally unacceptable concentrations of these residual contaminants for which limits have been established.

Removal of Other Heavy Metals. Tables 2 and 3 show the effectiveness of removal of 10 metals tested using the starch xanthate-cationic polymer method. For comparison similar metal solutions were treated with sodium hydroxide to precipitate the metals as their hydroxides. The tables also list the solubility product constants for the metal ethyl xanthates. The constants are useful in determining how effectively the metal will be removed with the starch system.

Scale-Up. The method has been scaled-up to 25 gallons of metal solution. Table 4 shows the concentrations of residual metal.

Testing of Other Cationics. Several cationic polymers have been evaluated. Table 5 compares the effectiveness of several polymers ranging in price from $0.13 to $1.50 per pound.

Advantages of the Method. Several important advantages of the starch xanthate-PVBTMAC method are apparent. Metal recovery for reuse is possible with mild acid treatment of the complex. The volume of sludge to be treated for recovery of the metal or to be disposed of is small compared to that obtained from several other processes. The physical nature of the sludge is not gelatinous as with usual basic precipitation and the floc settles faster and can be removed easier. Some methods require the removal of suspended solids before treatment; however, this is not necessary with the xanthate method. The starch xanthate method is effective over a pH range of 3-11.

Table 2.--Heavy metal removal from solutions of individual metals by treatment with starch xanthate-PVBTMAC (final pH 7) vs. 0.1N sodium hydroxide (pH 7 and 9)

Metal	Treatment	Starch Xanthate (ml)[1]	Initial pH	Initial Concn. µg/l	Residual Concn. µg/l	Illinois Limit[2] µg/l	pH, Optimum for Hydroxide Precipitation[5]	Ksp Metal Ethyl Xanthate[3]
Cd^{+2}	Xan-PVBTMAC	4.65	3.1[4]	56,200	8	50	6.7	2.6 X 10^{-14}
	NaOH (pH 7)		2.9	56,200	29,600			
	NaOH (pH 9)		2.9	56,200	4,500			
Cr^{+3}	Xan-PVBTMAC	3.45	4.5[4]	26,000	52	1,000	5.3	---
	NaOH (pH 7)		3.0	26,000	3,800			
	NaOH (pH 9)		3.0	26,000	416			
Cu^{2}	Xan-PVBTMAC	4.50	3.0[4]	31,770	12	20	5.3	5.2 X 10^{-20}
	NaOH (pH 7)		2.9	31.770	1,100			
	NaOH (pH 9)		2.9	31,770	24			
Fe^{+2}	Xan-PVBTMAC	3.40	3.7[4]	27,920	2,980	1,000	5.5	8.0 X 10^{-8}
	NaOH (pH 7)		2.6	27,920	2,920			
	NaOH (pH 9)		2.6	27,920	14,500			
Fe^{+3}	Xan-PVBTMAC	3.70	3.65	27,920	890	1,000	2.0	---
	NaOH (pH 7)		3.65	27,920	146			
	NaOH (pH 9)		3.65	27,920	15			
Pb^{+2}	Xan-PVBTMAC	4.60	3.1[4]	103,600	8	100	6.0	2.0 X 10^{-17}
	NaOH (pH 7)		3.0	103,600	34,500			
	NaOH (pH 9)		3.0	103,600	8			
Mn^{+2}	Xan-PVBTMAC	4.10	3.2[4]	27,470	10,700	1,000	8.5	10^{+2}
	NaOH (pH 7)		3.0	27,470	10,700			
	NaOH (pH 9)		3.0	27,470	9,600			
Hg^{+2}	Xan-PVBTMAC	4.70	3.2	100,000	3.8	0.5	7.3	1.7 X 10^{-38}
	NaOH (pH 7)		3.2	100,000	>10,000			
	NaOH (pH 9)		3.2	100,000	8,140			
Ni^{+2}	Xan-PVBTMAC	4.15	3.3[4]	29,350	275	1,000	6.7[6]	1.4 X 10^{-12}
	NaOH (pH 7)		3.2	29,350	5,820			
	NaOH (pH 9)		3.2	29,350	4,350			
Ag^{+1}	Xan-PVBTMAC	4.52	3.2	53,935	3	5	9.0[6]	5.0 X 10^{-19}
	NaOH (pH 7)		3.2	53,935	15,800			
	NaOH (pH 9)		3.2	53,935	14,800			
Zn^{+2}	Xan-PVBTMAC	4.10	3.6[4]	32,680	3,300	1,000	7.0	4.9 X 10^{-9}
	NaOH (pH 7)		3.3	32,680	6,900			
	NaOH (pH 9)		3.3	32,680	1,010			

---

[1] Starch xanthate (DS=0.23) required for maximum metal precipitation in 50 ml of metal solution at pH 7, after one ml of PVBTMAC of 1 percent concn. is added.

[2] State of Illinois discharge limits for public and food processing waters [Illinois Pollution Control Board, Newsletter No. 44, p. 7 (March 1972)].

[3] Kakovsky, I. A., "Physicochemical Properties of Some Flotation Reagents and Their Salts with Ions of Heavy Non-Ferrous Metals." *Proc. Int. Congr. Surface Activ. 2nd*, 4, 225 (1957).

[4] pH increased so final solution after treatment would have a pH of 7.0.

[5] Dean, J. G., *et al.*, "Removing Heavy Metals from Waste Water." *Environ. Sci. Technol.*, 6(6), 518 (1972).

[6] Diehl, H., and Smith, G. F., "Quantitative Analysis." John Wiley & Sons, Inc., New York, N.Y. (1952).

Table 3. Heavy metal removal from solutions containing a mixture of them by treatment with starch Xanthate-PVBTMAC (final pH of 7) vs 0.1N sodium hydroxide (pH 7 and 9)

Treatment	Sample (µg/l)									
	Cd^{+2}	Cr^{+3}	Cu^{+2}	Fe^{+2} Fe^{+3}	Pb^{+2}	Mn^{+2}	Hg^{+2}	Ni^{+2}	Ag^{+1}	Zn^{+2}
None	5,620	2,600	3,177	5,484	10,360	2,747	10,000	2,935	5,394	3,268
Xan-PVBTMAC[1]	3	21	16	990	8	1,510	3.8	57	5	319
NaOH (pH 7)	2,978	42	151	79	180	1,508	4,580	1,610	93	1,800
NaOH (pH 9)	390	31	20	34	8	833	4,275	681	62	53
Illinois limit	50	1,000	20	1,000	100	1,000	0.5	1,000	5	1,000

[1] Starch xanthate (DS=0.23) and 1 ml of PVBTMAC of 1 percent concn. were added to 50 ml of the metal solution.

Table 4. Heavy metal removal from 25 gallons of solution by treatment with starch xanthate-polyethylenimine (PEI)

Treatment	Metal ppb							
	Cd^{+2}	Cr^{+3}	Cu^{+2}	Fe^{+2}	Pb^{+2}	Hg^{+2}	Ni^{+2}	Ag^{+1}
None	5,620	2,600	3,177	5,484	10,360	10,000	2,935	5,394
St-xan-PEI[1]	27	22	3	100	8	2	77	3
Illinois limit	50	1,000	20	1,000	100	0.5	1,000	5

[1] Starch xanthate (0.23 DS) - 79.6 g (d.b.) and PEI (Montrek 1000) - 18.9 g (d.b.).

Table 5. Evaluation of several cationic polymers with starch xanthate for removing heavy metals

Treatment	Metal (ppb)[1]									
	Cd^{+2}	Cr^{+3}	Cu^{+2}	Fe^{+2}	Pb^{+2}	Mn^{+2}	Hg^{+2}	Ni^{+2}	Ag^{+1}	Zn^{+2}
None	3,620	2,600	3,177	5,484	10,360	2,747	10,000	2,935	5,394	3,268
St-xan-PVBTMAC[2]	7	0	3	66	8	1,179	3.6	45	3	73
St-xan-PEI[3]	35	11	2	42	8	83	Tr	135	3	67
St-xan-CPA[4]	10	0	1	50	8	1,093	Tr	61	5	77
St-xan-CSt-1[5]	30	44	6	583	8	1,083	Tr	338	5	1,037
St-xan-CSt-2[6]	83	11	15	92	8	833	Tr	354	8	210
St-xan-AEWF[7]	26	0	6	100	8	1,083	Tr	69	13	73
Illinois limit	50	1,000	20	1,000	100	1,000	0.5	1,000	5	1,000

[1] Metal concentration determined by atomic absorption with a Varian Techtron AA120 spectrophotometer.

[2] PVBTMAC, 0.2 g/l.; st-xan, 0.78 g/l.

[3] PEI, 0.2 g/l.; st-xan, 0.84 g/l.

[4] CPA (a commercial cationic polyacrylamide, Reten 220), 0.2 g/l.; st-xan, 0.34 g/l.

[5] CSt-1 (a commercial cationic starch, "Cato 8"), 0.4 g/l.; st-xan, 0.26 g/l.

[6] CSt-2 (a commercial cationic starch, "Cato 15"), 0.4 g/l.; st-xan, 0.28 g/l.

[7] AEWF (aminoethylated wheat flour), 0.4 g/l.; st-xan, 0.34 g/l.

Additional Information. In the previous discussion it was shown that the fairly expensive cationic polymer was necessary for effective removal. Recently, the process has been modified to eliminate the cationic polymer and utilize only starch xanthate to effect heavy metal removal.

The starch xanthate in this modified process is water insoluble and is produced by reacting a highly crosslinked starch with sodium hydroxide and carbon disulfide. The insoluble starch xanthate is mixed with the metal effluent where it reacts with metals and is then separated yielding "clean effluent". The insoluble starch xanthate-metal complex can be broken by nitric acid yielding insoluble starch, sulfuric acid and metal ions which can then be recovered.

Table 6 shows the effectiveness of solid starch xanthate in removing heavy metals from water. Effective removal is always in the pH range of acceptable pH discharge (pH 6-9). A stirring time of 2 hours is advantageous for complete removal.

Table 6. Removal of heavy metals by treatment for two hours with insoluble starch xanthate

Metal	Initial Concn. µg/1.	pH Initial	pH 2 hours	Residual Metal µg/1.	Illinois Discharge Limit µg/1.
Cu^{+2}	31,770	3.4	6.4	7	20
Ni^{+2}	29,350	3.2	7.7	19	1,000
Cd^{+2}	56,200	3.0	6.8	9	50
Pb^{+2}	103,600	3.1	7.3	25	100
Cr^{+3}	26,000	3.2	6.5	3	1,000
Ag^{+1}	53,935	3.1	7.2	245	5
Zn^{+2}	32,680	3.1	7.5	46	1,000
Fe^{+2}	27,920	3.0	6.4	0	1,000
Mn^{+2}	27,470	3.3	9.0	1,628	1,000
Hg^{+2}	100,000	3.1	4.2	3	0.5

Metal release from the product using nitric acid is effective and the metal is recovered as a concentrated metal solution. The xanthate is oxidized by the acid to sulfate and the insoluble starch is recovered for rexanthation and reuse.

Other Literature

"Recovering Heavy Metals," _Agricultural Research_, 21(9), 3-4 (1973).

"Mercury Removal from Wastewater with a Starch Xanthate-Cationic Polymer Complex," C. L. Swanson, R. E. Wing, W. M. Doane and C. R. Russell, _Environ. Sci. Technol._, 7(7), 614 (1973).

"Removal of Heavy Metal Ions from Wastewater with a Starch Xanthate-Cationic Polymer Complex," R. E. Wing, C. L. Swanson, W. M. Doane and C. R. Russell, _J. Water Pollut. Contr. Fed._ (submitted).

POTENTIALLY USEFUL PRODUCTS DERIVED FROM GLUTEN HYDROLYZATE

K. Gutfreund and T. Yamauchi
IIT Research Institute

Gluten hydrolysate obtained from wheat flour was modified in a series of reactions with ethylene oxide and ethyleneimine. The extent of the reaction indicated appreciable involvement of carboxyl and NH groups of the polypeptide. Epoxidized gluten imparted pressure sensitivity to selected acrylic adhesive formulations. The peel strength of these adhesives depended on the relative amount of epoxidized protein and the nature of acrylic monomer. Ethyleneimine-modified gluten used as an additive improved the mechanical properties of inherently brittle gluten hydrolysate films. The applicability of modified polypeptide for preparation of water-soluble packaging films, plasticizers, and processing additives was investigated.

Among the polypeptides that have found commercial application, those derived from silk fibroin, casein, and zein have received the main attention, as suggested by Koch (1), Rutherford (2), and Blackburn (3). Unlike these proteins, gliadin and glutenin derived from wheat found little use, partly because of the relative insolubility of gluten, the inherent chain rigidity (lack of plasticity), and the limited knowledge of their structure and properties. The hydrolysis of gluten produces polypeptides simpler than the parent material, and their lesser complexity offers better possibilities for their commercial utilization through appropriate modification or conversion.

These considerations suggested the use of gluten hydrolysate as a starting material for reactions with organo-functional compounds capable of interacting with hydroxyl, carboxyl, sulfhydryl, and primary- or secondary-amine groups. The intended approach was based on the attachment of long side chains to the polypeptide backbone at the reactive sites. The polar nature of the protein would thus become much less pronounced, and the increased oleophilic character of the modified polypeptide would permit its further reaction with nonpolar organic compounds.

Among the compounds considered for reaction with gluten hydrolysate were ethylene oxide (ETO) and its nitrogen analog, ethyleneimine (ETI). These reagents are capable of interacting with hydroxy, carboxy, and sulfhydryl functional compounds. Also, the ethoxy- and the imino-functional monomers could, in the process of grafting to the polypeptide, form higher-molecular-weight aggregates, and the protein would thereby be converted to an organic polymer having properties greatly different from those of the parent material.

Reactions of proteins with ethoxy-functional compounds have been the subject of previous investigations. Immunological studies by Maurer (4) provided evidence of extensive alteration of human serum proteins after treatment with ETO. Investigations of the interaction of ETO with egg albumin and beta-lactoglobulin by Fraenkel-Conrat (5) suggested preferential reaction of sulfhydryl groups, while phenolic and hydroxylic groups showed 80 and 45 to 75% substitution, respectively. Not much information on the involvement of secondary amine groups in the epoxidation of proteins has been obtained. However, in similar studies by Rafikov (6) on polyamides, the degree of NH-substitution varied from 7.5 to 51%, depending on the reaction conditions.

The multiplicity of potential reaction sites on the polypeptide chain introduces the problem of variation of the properties of modified protein with the locus or loci of attached side chains. Thermal conditions and the use of catalysts also influence the nature of products obtained, as demonstrated in Jones' (7) and Trout's (8) reactions with ETI.

In the preliminary phase of our investigations it appeared desirable to discount the complications arising from the specificity of a given reaction and to focus attention on the conditions that could produce, in a relatively simple process, maximum changes in the protein so that could be either directly utilized as a resin or in resin systems or applied as a reactive intermediate for polymerization with selected monomers. These reactions are discussed below.

Ethylene Oxide (ETO) Reactions. Acid gluten hydrolysate (AGH) and ETO mixed in weight proportions ranging from 1:2 to 1:10 AGH:ETO were allowed to react for 48 hr at 85°C in a stainless-steel pressure bomb. The existing pressure in the reaction vessel, based on vapor-pressure data for ETO at 4.9°C (400 mm Hg) and at 10.7°C (760 mm Hg), was approximately 8 atm at 85°C.

The epoxidized products (ETOG) obtained increased in consistency with increasing amounts of AGH and gradually changed from a liquid to a semisolid. Reactions with 1:3 and 1:2 AGH:ETO had to be conducted by tumbling the pressure bomb at the reaction temperature to provide optimum contact between reagents and to ensure homogeneity of the reaction product. In most secondary reactions of epoxidized gluten with organic monomers and polymers, ETOG containing 1:5 AGH:ETO was used. The product contained 17 wt.% polypeptide and was a low-viscosity fluid. It was soluble in water, methyl alcohol, acetone, and methylene chloride but insoluble in ether, carbon tetrachloride, and n-hexane.

Alkyleneimine (ETI) Reaction Products. The reactivity of ETI with sulfhydryl- and carboxy-functional compounds suggested the use of this nitrogen analog of ETO for modification of gluten. The application of ETI homopolymers in synthetic fibers (9), cellulosic films (10), flocculating agents (11), and ion-exchange resins (12), made utilization of this compound in reactions with AGH particularly attractive.

The initial reaction was performed in a 10% pyridine solution of gluten hydrolysate with aluminum chloride catalyst. ETI in a 20% pyridine solution was introduced through a dropping funnel. The entire system was placed in a polyethylene enclosure filled with continuously flushed dry nitrogen to prevent hydrolysis of the imine. The reaction temperature was gradually raised from 65 to 135°C while additional amounts of ETI were added to the reaction vessel to achieve a 50% total weight of solids after 3 hr. After 3 hr the solution was cloudy, and the separated solid was removed by filtration through a fritted-glass filter. An additional voluminous precipitate formed when the supernatant was treated with ether. The precipitated solid, freed from occluding pyridine by ether washing, was soluble in water.

As a corollary of the ETI/AGH reaction in pyridine, a similar reaction was performed in the pressure bomb without solvent. When the system (1:5 AGH:ETI) was heated for 24 hr (and for 48 hr in another experiment) at 60°C, a yellow gel-like product resulted. The product, EIG, was soluble in water and formamide but insoluble in pyridine, methylene chloride, ether, acetone, tetrahydrofuran, and methanol. When the gel was dispersed in methylene chloride or methanol, a white powder separated. The powder, similar to that recovered from the reaction in pyridine, showed surface-active properties in aqueous solution.

A viscous liquid, recovered from methylene chloride after preparation of the precipitate obtained from the gel, polymerized on exposure to air containing moisture. This product appeared to be a homopolymer of ETI.

Characterization of Products. The solubility of ETOG in organic solvents (methanol, acetone) appeared to support the assumption that this compound had oleophilic side chains grafted to the polypeptide backbone. In general, polypeptides are soluble in typical polyamide solvents, such as dimethyl formamide (DMF), phenol, and m-cresol, or in strongly interacting solvents, such as trifluoroacetic acid and dichloroacetic acid. However, polypeptides that contain bulky side chains, e.g., polybenzyl glutamate, are modified sufficiently to be soluble in chloroform and dioxane. Therefore the solubility of ETOG in organic solvents could be attributed to polyoxyethylene chains grafted on the gluten hydrolysate.

To clarify the relationships involved in the reaction of ETO with AGH, comparative infrared spectra were obtained for the parent and modified polypeptide. Figure 1 indicated the disappearance of an absorption peak (A) for gluten hydrolysate after epoxidation. This peak, which occurred at approximately 6.5μ, is characteristic of an NH vibration mode associated with the $-\overset{O}{\overset{\|}{C}}-NH$ grouping. The observed effect therefore suggested the reactivity of the secondary amine toward ETO. The occurrence of an absorption band (B) at approximately 3μ in both spectra indicated the presence of OH groups in the parent and the modified polypeptide, a result suggesting the possibility of involvement of the COOH groups in the reaction with ETO, since terminal OH groups are formed at the end of a polyether chain in epoxidation processes. Since the OH band can be obscured by an NH-stretching mode, it is difficult to determine

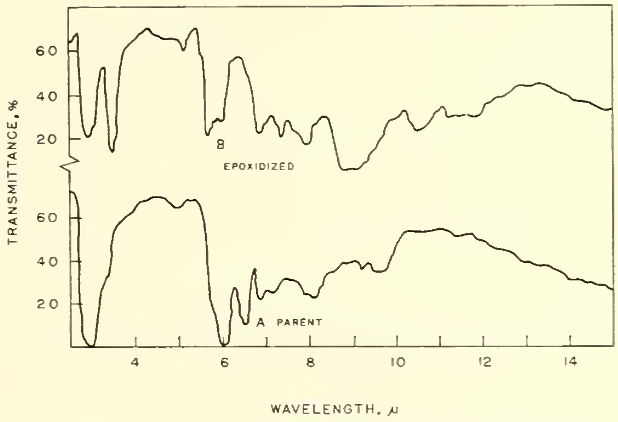


Figure 1. Infrared spectra of epoxidized and parent gluten hydrolysates.

from infrared data which of the polypeptide functional sites is primarily responsible for the reaction with ETO.

Chemical Studies of Functional Relationships. The indication that specific groups on the polypeptide were involved in reactions with ETO and ETI suggested determining the functional relationships in AGH before and after reaction with ETO and ETI. Particular attention was given to acidic and hydroxyl sites.

The pertinent measurements followed procedures similar to those used for the determination of acidic and acetyl numbers of carboxyl- and hydroxy-functional organic compounds. In the analysis of AGH, ETOG, and EIG for carboxyl-group content, the samples were heated for 48 hr at 60°C in a vacuum oven maintained at 2 mm Hg and dissolved or dispersed in dry DMF. Titrations were performed with 0.1 N sodium methoxide or sodium hydroxide. Approximately 1 to 3% solutions of modified and unmodified protein hydrolysate were used, and the titrations were performed in a nitrogen atmosphere with phenolphthalein indicator.

The acetylation reaction was carried out under reflux (60°C) in round-bottom flasks containing 10 ml of a 10% solution of AGH, ETOG, and EIG in DMF and 25 ml of an 8% solution of reagent-grade acetic anhydride in dried pyridine. After 2 hr a measured amount (5 ml) of water was added through the condenser tube to the system, and the reaction was continued for 10 min under reflux. The reaction system was cooled to room temperature and titrated with 0.5 N sodium hydroxide. Because the solution was colored, visual indicators could not be used for end-point determination. The titration was therefore followed by potentiometric measurements with a Fisher Acumet pH meter. In all experiments, blank titrations were used to make appropriate corrections for the amount of titrant used by solvents and secondary reagents.

The carboxyl-group functionality of AGH, expressed in milliequivalents of titrant consumed per gram of sample, was 0.76 meq/g. After epoxidation and ETI treatment, ETOG exhibited no residual carboxyl-group functionality and EIG consumed 0.04 meq/g of reagent. Acetylation of ETOG disclosed a hydroxyl-group concentration equivalent to 1.27 meq/g; the corresponding value for EIG was 3.57 meq/g. The value obtained for EIG appears high and might be in error because of the residual alkalinity of the reaction product of AGH with ETI. The complete depletion of carboxyl groups in AGH after reaction with ETO and the marked reduction of this functionality in EIG indicate extensive reaction of acidic sites on the polypeptide with ETO and ETI. The greater amount of acetylating reagent consumed in ETOG as compared with the amount of sodium hydroxide titrant used in AGH suggests that the carboxyl groups on the parent protein hydrolysate were not the only sites with which ETO reacted. Other groups that could have also been engaged include residual primary-amine groups, sulfhydryl groups, and possibly secondary-amine groups.

The involvement of secondary-amine groups with ETO has been demonstrated in reactions with polyamides (6) and could partly explain the effects observed. Formation of terminal hydroxyl groups in the reaction of ETO with carboxylic sites on the polypeptide was supported by amino acid-analysis data. A considerable loss of aspartic and glutamic acid resulted from the epoxidation of AGH. Other constituents whose recovery after ETO treatment was small and whose presence could be attributed to the blocking of hydroxyl groups included serine, threonine, and tyrosine.

Utilization in Adhesives. The compatibility of epoxidized gluten hydrolysate (ETOG) with organic compounds suggested the use of it with acrylic monomers such as hydroxymethyl methacrylate (HEMA), n-butyl acrylate (BUA), ethyl acrylate (EA), and octyl acrylate (OA) for the preparation of adhesives. Reaction of these monomers with ETOG for 20 min at 75°C in the presence of 2% tert-butyl hydroperoxide catalyst resulted in pressure-sensitive products whose adhesive properties depended on the proportion of reagents used. The pressure sensitivity of the adhesives applied to a Mylar-film substrate was determined by peel-strength measurements.

To eliminate experimental sources of error, particular care was taken in the preparation of multiple-peel test specimens. The reference substrate, stainless steel employed in 1- x 7-in. strips, was scrupulously cleaned with water and detergent and rinsed in methanol and distilled water. Coated films, 1 in. wide, were applied to the clean stainless-steel plates with a rubber squeegee. To employ the same bonding force for each specimen, each was subjected to a compressive stress of 150 psi for 1 min before testing.

The film was removed from the metal substrate at a peeling rate of 12 in./min with a 180° angle between the adhering and the peeled portions of the film. Peel strengths recorded for Mylar tape coated with 1:1 ETOG:HEMA ranged from 0.45 to 0.55 lb/in. Under equivalent conditions, peel strengths of 2.2 and 1.5 lb/in. were obtained for Scotch tape (Minnesota Mining and Manufacturing Company). The higher peel strengths for the commercial product may have resulted not only from quality differences in the adhesives compared, but also from differences in the nature of the polymeric films on which the coatings were deposited. The ETOG:HEMA formulation became detached from Mylar tape during peeling; adhesive failure between the relatively inert polymer and the adhesive rather than between the adhesive and the reference metal substrate was thus indicated.

Pressure-sensitive adhesives applied to cellophane failed consistently at the adhesive-metal interface. Therefore in subsequent experiments regenerated cellulose film was used as a backing for the experimental adhesives. The data obtained in these studies are summarized in Table 1. The results in the lower protion of Table 1 represent the adhesive peel strength of a paper substrate (manilla folder); two paper strips, bonded with the experimental adhesive, were pulled apart at an angle of 180°. The experiments represented by the upper portion of Table 1 were conducted with cellophane tape as the backing for the adhesive and with stainless steel as the reference substrate.

Table 1. Adhesion of modified gluten hydrolysate to steel and paper substrates.

Substrate	Composition, parts by weight					Adhesion, lb/in.		
	ETOG	HEMA	BUA	OA	EA	Min.	Avg.	Max.
Stainless steel	4	2	1	--	--	0.2	0.26	0.42
	2	3	1	--	--	0.8	1.0	1.2
	1	1	--	1	--	0.8	1.2	1.6
	2	2	1	--	--	1.5	2.0	2.3
	1	2	--	--	1	1.8	2.5	3.0
	1	1	--	--	1	2.0	2.8	3.2
Paper	1	1	--	--	1	0.18	0.2	0.2[1]
	2	2	--	1	--	0.2	0.3	0.6
	4	2	1	--	--	0.3	0.4	0.6
	2	2	1	--	--	1.4	1.8	2.4
Scotch tape	--	--	--	--	--	--	1.5	2.2

[1] Fiber tear.

The data indicate that formulations containing ETOG:HEMA:EA in 1:2:1 and 1:1:1 weight proportions exceed the adhesive peel strength of commercial adhesive tape on a stainless steel substrate. In applications involving paper, the maximum bond strength was exhibited by a formulation containing equal proportions of ETOG, HEMA, and EA; this system produced fiber tear within the paper, so the adhesive bond was stronger than the cohesive strength of the bonded material. Therefore appropriate modification of the basic ETOG/HEMA adhesive ensured a permanent bond between a paper label coated with this pressure-sensitive formulation. If used in different proportions and with other modifiers, clean release of the gummed label, as required for price-marked items, can be obtained. OA and BUA facilitated the release of paper from a paper substrate.

Under ordinary conditions the adhesive-bond strength obtained for cellophane film coated with ETOG/HEMA/acrylic-modifier formulations was relatively good. For optimum bonding, the amount of ETOG should be limited to less than 60 wt. % per total solids content, which is preferably 33%. The pressure-sensitive properties of these systems remained essentially unchanged during exposure to air for 8 weeks at 25°C and 45% RH.

Utilization in Films. The applicability of gluten hydrolysate to the preparation of films was explored. Particular consideration was given to the plasticizing effectiveness of modified protein in inherently brittle film-forming materials. Initial experiments were concerned with preparing polypeptide films by casting a 10% aqueous solution of soluble gluten hydrolysate (SGH, obtained by neutralization of the AGH) on a tin foil-covered glass substrate. The residual films, formed after evaporation of the aqueous phase, developed a multiple parallel-fracture pattern, which apparently resulted from the excessive shrinkage stresses to which the films were subjected during drying. The fractured films were extremely brittle, and attempts to remove them from the substrate resulted in pulverization of the polypeptide.

To reduce the susceptibility of gluten hydrolysate to brittle failure, ETOG was employed as a plasticizing additive in polypeptide films. The formulations from which these films were prepared contained gluten hydrolysate: ETOG in 1:1, 1:1.2, 1:1.5, and 1:2 weight proportions. Films having increasing amounts of ETOG exhibited a decreasing tendency to crack. The 1:1.5 gluten hydrolysate: ETOG provided an intact film after drying. After the tin substrate was removed by amalgamation, however, this film failed on bending. Much better flexibility was exhibited by a film that contained 66% ETOG per total weight of solids. This film could be folded 180° without failing.

To assess the benefits derived from ETOG and EIG additives in gluten films, the effect of both compounds on the mechanical properties of gluten films was determined. Since from the viewpoint of mass utilization of the parent material (gluten) it appeared desirable to use the smallest amount of modifier consistent with the mechanical integrity of the films, the properties of films containing SGH:EIG in 1:1, 2:1, 3:1, 4:1, 6:1, and 10:1 weight proportions were determined. Unlike unplasticized SGH, none of the EIG-modified films developed cracks during drying. However, a gradual increase in stiffness and brittleness was observed for specimens containing smaller amounts of EIG.

Since the practical use of films, e.g., in packaging applications, demands reasonable toughness (a large value of the product of tensile strength and elongation) and strength, the stress-strain properties of different film systems were determined in an effort to select a film having optimum properties. The results of this study are summarized in Figure 2.

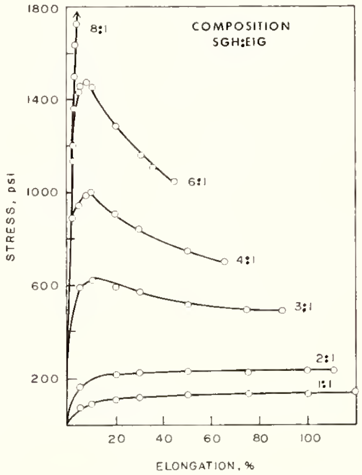


Figure 2. Stress-strain behavior of EIG-modified SGH films having different compositions.

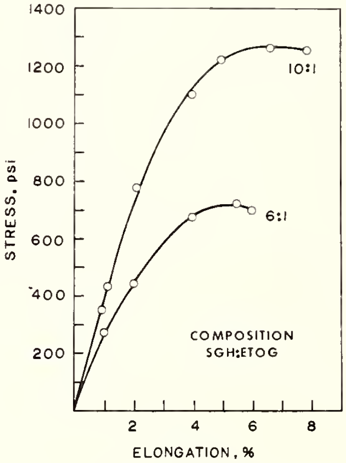


Figure 3. Stress-strain behavior of ETOG-modified SGH films.

It is evident that films containing less than 10% EIG are susceptible to failure at relatively small elongations. Specimens obtained from the 8:1 SGH:EIG system developed an ultimate elongation of 3 to 4%, but their 10:1 analogs failed at 1 to 2% elongation. These results and those obtained for 2:1 and 1:1 SGH:EIG films, which exhibited a relatively low strength (100 to 200 psi), suggest the use of modified protein films with 3:1 to 6:1 SGH:EIG. The yield stress of 1500 psi and the elongation of 15% represent respectable mechanical properties of the 6:1 SGH:EIG film. Therefore this film could find commercial use in specialty packaging products. (The potential application of this material is discussed later.)

In corollary studies of the mechanical behavior of ETOG-modified SGH, stress-strain measurements were performed on films prepared from two formulations. The results, presented in Figure 3, indicated a better plasticizing action of ETOG than EIG. However, the mechanical properties of ETOG-modified SGH were poorer than those obtained for the polypeptide containing an equivalent amount of EIG. Only the 10:1 SGH:ETOG system provided a film having acceptable mechanical properties (1200 psi at 7% elongation). The 6:1 formulation produced relatively weak films whose pronounced moisture sensitivity imposed severe limitations on their use as packaging materials.

Utilization in Filaments. By extending the application of epoxidized gluten hydrolysate to a fiber-forming or a fiber-modifying component for textile uses, several reactions were performed with ETOG and hydroxypropyl methacrylate (HPMA). Initial experiments with the polymerization product of 1:2 ETOG:HPMA, catalyzed with 2% tert-butyl hydroperoxide, provided filaments having relatively poor surface properties when extruded through a 1/32-in. orifice at 40°C. The poor surface quality of the extrudate was attributed to the low extrusion temperature.

To determine the effects of composition on the quality of the filaments, a series of experiments with ETOG and HPMA were performed. ETOG:HPMA formulations were prepared in 2:1, 1:1, 1:2, 1:2.5, and 1:3 weight proportions, and the modified protein-acrylic systems were polymerized in the presence of 1% tert-butyl hydroperoxide at 75°C for 25 min. The reaction products hardened to semisolids when cooled to room temperature (25°C), but they could be fluidized by heating.

A small 0.5-in.-ID extrusion device, consisting of a stainless-steel tube closed at one end and provided with a 1/65-in.-ID orifice attachment fit into the lower portion of the side wall of the tube, was designed. The tube, filled with extrusion polymer, was closed at the top with a well-fitting nylon disk, which was later pushed against the polymer by a steel ram. The crosshead of the Instron machine moved at a rate of 0.05 in./min and supplied the driving force to the ram. The side wall of the extruder, wrapped in heating tape, was heated to 90°C, and after reaching thermal equilibrium, the polymer was extruded through the orifice on an Instron machine. The extruded filament was wound on a 3-in.-ID mandrel at a peripheral speed that exceeded the linear rate of extrusion in order to facilitate further reduction of the filament diameter to 0.005 to 0.010 in.

The best results were obtained with 1:2 and 1:2.5 ETOG:HPMA formulations. The filaments had smooth surfaces, which pulled well without fracturing, and exhibited good flexibility.

Attempts to improve the mechanical properties (strength) of extruded filaments by using ethyl metacrylate (ETMA) or methyl methacrylate (MMA), were promising for a 1:1:1 ETOG:HPMA:MMA formulation. However, fibers prepared from 1:2 ETOG:ETMA were difficult to extrude and exhibited pronounced brittleness after cooling.

In measurements of the mechanical behavior of extruded filaments, attention was given to the deformability of fibers and their elastic properties in stress-relaxation and permanent-set studies. Stress-strain tests were performed on an Instron machine at an elongation rate of 0.5 in./min. The stress retained by the test sample after 5 min of relaxation at an elongation equivalent to that of a specimen extended to 50% of its breaking strength was recorded as percent residual stress. Permanent set was measured after the specimens that underwent stress relaxation were allowed to recover (without load) for 30 min. The results obtained for filaments containing ETOG:HPMA in 1:2 and 1:2.5 weight proportions are shown in Table 2.

Table 2. Mechanical properties of acrylic modified ETOG filaments

Property	Composition, parts by weight 1:2 ETOG:HPMA	 1:2.5 ETOG:HPMA
Breaking strength, kg/cm^2	17.4	25.5
Elongation, %	370.0	265.0
Residual stress, %	34.0	38.0
Permanent deformation, %	7.5	6.5

As indicated in Table 2, modified ETOG filaments have a relatively low tensile strength, approximately five times less than that of cellulose acetate, 10 times less than that of polyethylene, and 20 times less than that of nylon. This characteristic and the relatively large permanent deformation of stressed filaments do not make use of the fiber in textile applications particularly attractive. To qualify for such use, ETOG would have to be modified by coreaction with a greater amount of acrylic compound (which appears undesirable from a utilization viewpoint), or by reaction with more effective rigidizing organic compounds.

Utilization as Plasticizers. The plasticizing effectiveness of gluten derivatives was studied in a series of experiments with organic resins. Preliminary investigations were performed with a commercial epoxy resin (Epon 828, Shell Chemical Company). ETOG:Epon 828 in a 1:1 weight proportion was cured at 25°C with diethylenetriamine catalyst (10% by weight of epoxy resin). A flexible, leathery product resulted when cast as a 0.020-in. sheet, whereas Epon 828 alone provided a hard and relatively brittle material under the same experimental conditions.

Good results with ETOG as a flexibilizing agent were also obtained in its use with a commercial polyanhydride resin, PA (Gantrez-AN 139, General Aniline and Film Corp.). When cast from an aqueous solution, the hydrolyzed polycarboxy compound formed a clear film that was extremely brittle at low humidity and even at normal room conditions (40%RH). To offset this disadvantage, films were prepared from a formulation of 50% PA and 50% ETOG. Both constituents were dissolved in water to provide a 10% aqueous solution, based on the total solids content. This solution was heated for 2 hr at 70°C with a small amount of concentrated sulfuric acid added as a catalyst. After cooling, films were spread from this solution on tin foil-covered acrylic plates by means of a doctor blade. The films, whose final thickness after drying for 8 hr at 25°C ranged from 0.0004 to 0.0011 in., were removed from the substrate by amalgamation of the tin foil. Unlike the parent material, ETOG-modified PA films were very flexible and showed no tendency toward cracking.

The plasticizing influence of EIG and ETOG additives on SGH films was demonstrated in the mechanical behavior of the modified protein (Figures 2 and 3). These films also disintegrated rapidly upon immersion in water, a result suggesting their use in specialty packaging. To determine the value of EIG-modified SGH as a packaging material for measured amounts of a laundry detergent, small packages, glue-sealed bags contained 15 g of Tide were prepared. The wrapped product was released in water after 30 sec, when the bag immersed in the liquid disintegrated. The bags obtained from 6:1 SGH:ETOG films dissolved in water faster (15 sec) than those prepared from EIG-modified gluten films of equivalent composition. The marked tackiness of ETOG-containing films, however, made them less suitable for packaging.

Conclusion. Reaction products obtained from partially hydrolyzed wheat gluten and ETO or ETI were compatible with organic monomers and resins. In reactions with organic compounds, the modified protein intermediate showed potential for application in pressure-sensitive adhesives, plasticizers, water-soluble films, and processing additives.

Acknowledgments

This work was supported by the United States Department of Agriculture, Northern Regional Research Center, Peoria, Illinois.

The help provided by C. Aranyi in the preparation and characterization of gluten hydrolysate, G. Sumyk in the analytical studies, and E. Hawrylewicz in the guidance of this program is gratefully acknowledged. We also express our thanks to J. W. Wall of the Department of Agriculture for his helpful criticism and suggestions.

Literature Cited

1. Koch, P. A. Mod. Text. Mag. 35: 42 (1955).
2. Rutherford, H. A., Patterson, W. I., Harris, M. J. Res. Nat. Bur. Stand. 25: 451 (1949).
3. Blackburn, S., Carter, E. G. H., and Phillips, H. Biochem. J. 35: 627 (1941).
4. Maurer, P. H. J. Exptl. Med. 113: 1029 (1961).
5. Fraenkel-Conrat, H. J. Biol. Chem. 154: 227 (1944).
6. Rafikov, S. R., Chenokova, G. L., and Gribkova, P. N. Vysokomol Soedin 1(3): 378 (1959).
7. Jones, J. D.,et al. J. Org. Chem. 9: 125 (1944).
8. Trout, P. E., Tappi 34: 539 (1951).
9. Schmidt, W. G. Brit. Patent 796,294 (1958).
10. Rosser, C. M. U.S. Patent 2,828,237 (1958).
11. Weidner, C. L.,et al. U.S. Patent 2,995,512 (1961).
12. Sonnerskog, S. Acta Chem. and Scand. 11: 573 (1957).

AGRICULTURAL ALCOHOL IN AUTOMOTIVE FUEL--GASOHOL

William A. Scheller
Department of Chemical Engineering
University of Nebraska-Lincoln

Since the advent of the reciprocating engine, alcohol has been considered as a possible fuel. General research studies have been reported in the technical literature as early as 1921 (1). By 1936 the research had become quite specific. For example, Bridgeman (2) published a paper entitled "Utilization of Ethanol-Gasoline Blends as Motor Fuel". Prior to World War II large quantities of ethanol were used as motor fuel in Europe. During the war, the largest quantity of alcohol was used in the manufacture of explosives and other materials of war. However, special applications were also made of the ability of alcohol-water mixtures to dramatically increase the power output of super-charged piston-type aircraft engines. Since the end of World War II the use of alcohol as motor fuel has declined to almost zero.

Today with the specter of an "energy crisis" and automotive fuel shortages looming over us, interest has once again turned to alcohol as a possible energy source. Agricultural alcohol has certain attractive features associated with it, not the least of which is that it represents a renewable energy source.

Pure grain alcohol has a high octane number in the order of 106. When alcohol is added to a typical regular gasoline with a research octane number of 91.0, the octane of the blend is improved 1.6 octane numbers for each 5-percent increment of alcohol up to a concentration of 25%. This improvement is greater than expected by calculating the simple arithmetic mean of the mix. If the octane number of the starting stock is higher, we obtain less of an octane increment by adding the alcohol. On the other hand, if the initial octane number is lower than indicated here we obtain a somewhat greater increase by adding alcohol.

The power output of an engine is also increased as the alcohol content of the fuel is increased. In Figure 1 this effect is shown as determined in the laboratory with a Richardo single cylinder variable compression ratio engine. At any given compression ratio the engine power expressed as break mean effective pressure (BMEP) increases as the grain alcohol content is increased from zero to 30%. The increase in power output that is obtained as the compression ratio of the engine is increased is also apparent. When the compression ratio reaches 9:1, the octane number of the regular grade of fuel that was used is insufficient to prevent preignition. Thus the power falls off rapidly in the area of preignition at alcohol concentrations of less than about 20%.

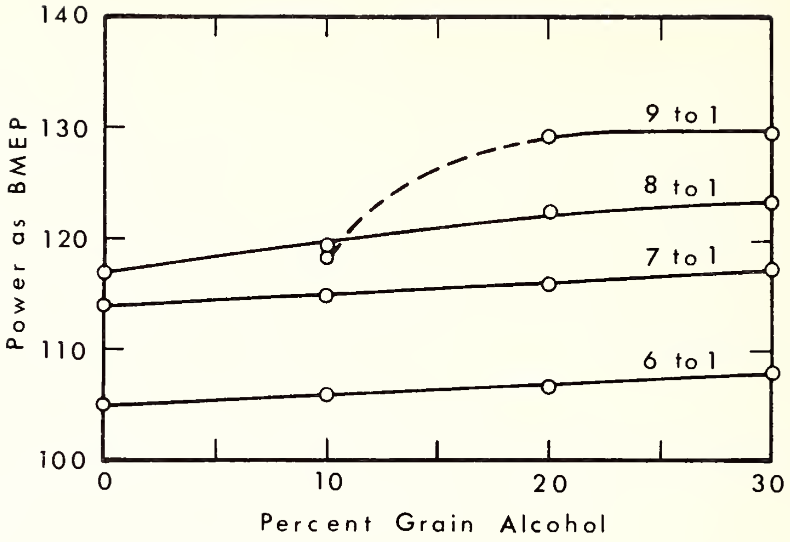
In Figure 2 the effect of grain alcohol concentration on the specific fuel consumption of the Richardo engine is shown. Again we see the improvement in fuel consumption associated with increasing the compression ratio of the engine. It should also be noted that the fuel consumption is initially reduced as the alcohol concentration is raised to a level of 10% to 20%. At a compression ratio of 9:1 the detrimental effect of preignition is again apparent as indicated by the curve at alcohol concentrations of less than about 20%.

Although these data were obtained from a stationary, single cylinder, four cycle engine, the trends seen here are also observed in dynamometer tests and road tests with typical passenger vehicles. The data used to prepare the power and fuel consumption charts was obtained by H. B. Mathur as a part of his Ph.D. thesis research (3). The octane-alcohol concentration data were published by the American Petroleum Institute as a part of a review article on the use of alcohol in motor gasoline (4).

The State of Nebraska has contributed to the knowledge and literature on alcohol-fuel usage through programs in the late 1930's, the late 1940's and the early 1960's (5). Their most recent activity in this field began in 1971 with the passage of legislative bill LB 776 and an update of this bill in the 1972 legislative session (LB 1208). These bills establish a reduction of 3¢ per gallon in the State gasoline tax for "gasoline sold in Nebraska which contains a minimum of a 10% blend of agricultural ethyl alcohol of at least 190 proof". They also establish an "agricultural alcohol fuel tax fund" to provide a program for implementation of a Nebraska agricultural alcohol industry for automotive fuels. The monies for this fund are derived by retaining 1/8 of a cent per gallon of the refundable portion of the State gasoline tax resulting from non-highway usage of gasoline in the State.

The bills also establish the Agricultural Products Industrial Utilization Committee to administer these funds. The seven committee members must be engaged in farming, business, and the petroleum industry. Three committee advisers are also required, one each from the Department of Economic Development, the University of Nebraska and the Department of Agriculture. Together, these ten people have worked out the current gasohol program for Nebraska. As used in this paper, the term gasohol means a mixture of 10% agriculturally derived ethyl alcohol and 90% gasoline.

Figure 1. Effect of alcohol on engine power



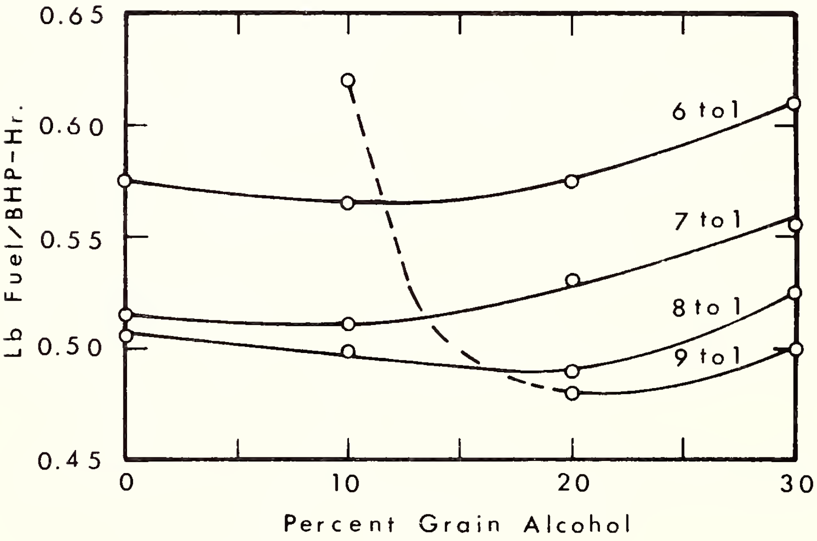
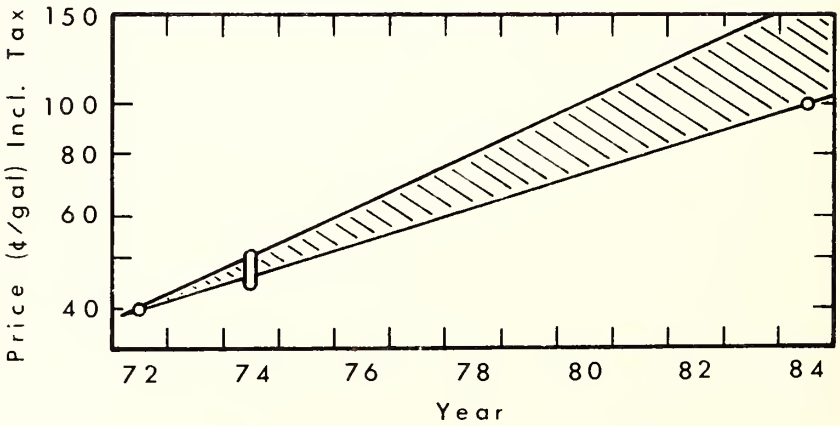


Figure 2. Effect of alcohol on fuel consumption

Figure 3. Projected gasoline price at the pump



The first undertaking of the committee after a short period of initial organization was to carry out an extensive literature search on the use of alcohol as a fuel additive. As a result of this search, certain things became apparent. Most significant of these are:

1. No data existed (at the time of the search) on the use of alcohol-gasoline blends in current or projected automotive engines.

2. No data could be found on exhaust gas compositions from alcohol blends in current or projected engines types.

3. No extensive fleet test had been made to determine the statistical performance of a large number of vehicle types on alcohol-gasoline blends.

4. The economics for the fermentation process used in producing ethyl alcohol from grain is highly sensitive to the market for the principle by-product, distillers dried grains.

Programs Funded. In view of these findings, the committee has established and funded the following programs:

1. An exhaust gas analysis program for the precise measurement of CO_2, CO, NO_x and unburned hydrocarbons. The purpose of this program is to obtain precise measurement of the difference in composition between exhaust gases from engines fueled with gasohol and from engines fueled with conventional gasoline. After careful study, a high resolution mass spectrometer was selected as the most suitable analytical instrument. This instrument has now been calibrated and preliminary analysis to date indicate no significant difference in the exhaust gas compositions.

2. A preliminary road test program involving five vehicles was initiated to identify any major problems which might exist in using gasohol fuel. This test also provided preliminary data for the design of an extensive fleet testing program for gasohol. The five vehicles used in the preliminary test were two 1972 Plymouth Fury's with V-8 engines, two 1972 Dodge 1/2-ton pickup trucks with V-6 engines, and one Mazda automobile with a Wankel engine. The fuel used in the preliminary test was 90% lead free gasoline and 10% anhydrous ethanol. After about 250,000 miles of driving we can report the following observations:

   a. Gas mileage appears to be at least as good as with leaded gasoline.
   b. No unusual engine wear has been found.
   c. Exhaust gas composition appears to be the same as with lead free gasoline.
   d. Drivers report no significant difference in performance.
   e. No water separation problems were found, not even at winter temperatures.

3. A design for a two million mile fleet testing program was prepared to permit gathering statistically significant data on fuel consumption (± 5% with 99% confidence), engine and exhaust system wear and vehicle performance with gasohol relative to conventional gasoline. The testing program itself has been approved by the Ag Products Committee and is awaiting funding from the next session of the Nebraska Legislature.

4. A final and very significant step taken by the committee was to initiate a preliminary study on upgrading the value of distillers dried grains, because of their importance in the overall economics of the production of ethyl alcohol from grain fermentation.

Economic Future of Gasohol. At least three factors are important to the economic future of gasohol. They are:

1. The price of gasoline.

2. The price of grain.

3. The value of by-products from the alcohol manufacturing process.

The price of gasoline is increasing rapidly as can be seen from Figure 3. A price of $1.00 per gallon appears to be a very likely possibility in the next seven to ten years. Forrest Shumway president of Signal Oil Company, said in a recent interview "I would be the most surprised guy around if I were not paying $1.25 and soon" (6).

The price of grain is also important to the gasohol picture. There is not enough damaged grain available to meet the needs of our program. Prospects of more normal wheat harvests in Russia and Australia, however, do imply the possibility of a return to lower grain prices in the future. On the other hand, the value of the distillers dried grains, the principle by-product of a fermentation alcohol plant, is also related to the price of the feed grain.

Prospects for upgrading the distillers dried grains to a product suitable for human consumption are encouraging. Another approach is to use a process such as that being developed by the Far-Mar-Co to separate the grain into component fractions before processing which could greatly reduce the by-product production and manufacturing costs associated with the alcohol process.

The future for gasohol looks bright.

Literature Cited

1. Tizard, H. T., Pye, D. R., "Character of Various Fuels for Internal Combustion Engines," pp 1-47, Empire Motor Fuels Comm. Rpt., The Institute of Auto. Engineers, London, Sess. 1923-1924.

2. Bridgeman, O. C., "Utilization of Ethanol-Gasoline Blends as Motor Fuels," Ind. Eng. Chem. 28:1102 (1936).

3. Mathur, H. B., "Effects of Ethanol Blending on the Performance and Exhaust Emission of Spark Ignition Engines," Ph.D. Thesis, Dept. of Mechanical Engineering, Indian Inst. of Tech., New Delhi, June 1971.

4. American Petroleum Institute, "Use of Alcohol in Motor Gasoline - A Review," Publication No. 4082, August 1971.

5. Lawrason, G. C., Finigan, P. F., "Ethyl Alcohol and Gasoline as a Modern Motor Fuel," pp 34-40, SAE Special Publication, SP-254, June 1964.

6. Wall Street Journal, March 16, 1973, page 1. "Prices of Gasoline are Likely to Climb, Perhaps very Sharply."

INSULATION MATERIALS DERIVED FROM CARBONIZED EXPANDED CEREALS

Victor Riley
Department of Civil Engineering
University of Toronto

Carbon Beads As Insulators. The idea of producing insulating carbon beads and other related products from cereals was patented (1) in 1972, and development work since then has been carried out by a private Toronto firm: TDR Engineering Developments Ltd. This development work has included extensive testing, and cost and marketing studies. In addition, studies have also been done by interested groups and firms throughout the world. The purpose of this paper is to provide a general description of the process, and to summarize some of the results of these studies.

In general, thermal insulation is achieved by enclosing air in finely divided cells or pockets, and all commercial insulation materials are based on this principle. Mineral wools, for example, perform well since pockets of air are contained within their fibrous structure, and foamed concrete, which also provides insulation, has a porous structure of air bubbles throughout. These air pockets, however, must be very small to prevent convection heat transfer within the contained air, and the degree of insulation usually increases with the fineness of the cell structure. Expanded polyurethane foams provide the highest degree of insulation of all commercial insulators because they have extremely finely divided cells. If an insulation material is to be successful, it must also have other characteristics. For example, it must also be resistant to moisture infiltration since even small amounts of moisture will greatly decrease the insulation value by allowing conduction heat transfer throughout the material. Mineral wools, vermiculites, perlites, and many other insulating materials perform poorly in this respect because of high moisture absorption, and so must be used in dry environments. Insulators should also be fireproof when used in buildings, and most types of organic materials such as expanded polyurethane foam are highly flammable and release toxic gases. Organic foams become unstable at higher temperatures, and this also limits their use. One method of overcoming these disadvantages is to combine organic insulators with inorganic heat resistant materials. For example, it is now common practice to produce insulating concretes by combining expanded polystyrene beads with portland cement paste. However, these beads have poor dimensional stability since they can be compressed, and so it is difficult to obtain volumetric control when producing prefabricated components such as panels or blocks. This illustrates yet another requirement for a successful insulating material: It must be dimensionally stable.

It is interesting to note that carbon cellular beads are satisfactory in most of these respects. They do not absorb moisture readily, and are fire resistant since most of the volatile gases have already been released on carbonization. In effect, they are already in the form of the char similar to that which forms on timber when it burns, and this protects the timber from further burning. Large sections of timber have good fire resistance ratings in building codes because of this behavior. In a recent disaster in Toronto, a large arena (Tam O'Shanter) burned down. The only structural members which survived the fire intact were the large laminated timber beams supporting the roof. The steel columns and other materials experienced total collapse. Carbon beads also have good resistance to high temperatures if they are enclosed in a matrix of, say, refractory cement. In fact, carbon has greater stability at high temperatures than most other materials known. Carbon also has a brittle structure, and therefore good dimensional stability for moulding operations.

With all these advantages, it seems reasonable that we should attempt to produce insulating carbon materials, and it turns out that this can be done very simply by expanding and carbonizing natural cereals, either alone, or in combination with other organic waste products. The basic procedures for this process are described in the next section.

Basic Process. Carbon can be derived from any type of organic material simply by heating the organic substance with the correct amount of air present. However, for the present process, the starting materials should preferably be expanded. This provides cellular, insulating structure, and also makes the process more economical since a small amount of starting materials can produce a large volume of insulation materials. Natural cereals such as corn, wheat, barley, rice, etc., can be expanded either by puffing or extrusion expansion which are well known processes in the food industry. Therefore, cereals are ideal starting materials. In practice, the cereals are expanded 20 to 30x by volume before carbonization. Most of the carbon in cereals is initially in the form of starch, and is released by the following reaction.

$$\underset{\text{(starch)}}{C_6H_{10}O_5} \xrightarrow{\text{heat}} \underset{\text{(carbon)}}{6C} + \underset{\text{(water)}}{5H_2O}$$

This reaction is an oversimplification since, in practice, gases such as CO_2 and CO are produced, and the carbon may contain impurities such as organic salts. Also, there are many non-starch components in cereals such as natural resins and oils. These are given off during carbonization in the form of volatile gases which can be burned to provide heat energy for the process. Experiments have shown that the carbon products have about 40 to 60% of their original weight depending on the temperature and amount of air present, and this is expected since cereals contain about 50% of carbon by weight. Also, it has been found that the ideal carbonization temperature is relatively low, in the range of 450°F to 600°F. Higher temperatures will lead to a loss of the carbon (2), and this is probably due to the porous structure of the expanded cereal.

All experiments to date have been carried out using corn, wheat, or rice as the starting materials, and these were used to produce discreet carbon beads having diameters varying from 1/8 inch to 3/8 inch. If expansion by puffing is used, then the size of the finished bead can only be varied by the degree of expansion since a whole grain must be used to begin with. Also, only certain types of cereals such as wheat or rice can be puffed. For extrusion, the cereals are ground into a powder, mixed with water and forced under pressure through an opening. This allows additional control on the size of the beads since the size of the opening or orifice can also be varied. Extrusion expansion also has other advantages; it is a continuous production process, and it can be used for most types of cereals. Therefore, extrusion expansion is the preferred industrial process.

If extrusion is used, it should be possible to combine various waste products such as corn cobs and potato peels with the cereals to reduce costs. At the time of writing this report, this has not been tried, but experiments are likely to be conducted in the future. Waste newspaper and other cellulosic products may also be a possibility, but the fibrous structure must be broken down before extruding and it is not yet certain that this can be done economically. Irrespective of what waste products are used, it is probable that a reasonable amount of cereals must still be included to give the cohesion and cellular structure to the final bead.

During carbonization of the expanded bead, some degree of shrinkage will occur and this shrinkage will be very severe if greater than about 4 to 5% by weight moisture is present in the uncarbonized beads. Normally, expanded cereals will pick up to 20% moisture from the air in normal conditions, and so care must be taken to keep the beads dry in laboratory experiments. This would not be a problem in an industrial process since the expanded dried beads are fed directly into the carbonization unit.

The carbonization can be carried out in any type of heated container with controls on the temperature and air inflow. However, since the beads are excellent insulators, they will not absorb heat very quickly unless they are kept in motion. Therefore, faster carbonization will occur in units such as rotary dryers which keep the beads in motion. In a typical experiment, carbonization was carried out in 10 minutes at 600°F in a small rotary dryer. Every attempt should be made to reduce shrinkage or overburning of the beads since this reduces the yield and increases cost.

It may also be possible to produce other types of insulating materials such as foam sheets, using the same basic process, but this has not been explored to date. All work is being concentrated on the production of discreet spherical beads.

General Properties. The final unit weight for the carbon beads depends on the volume expansion and weight loss which occur during carbonization. With present processes, the beads typically have a unit weight of 3.0 to 3.5 lb./cu. ft. The weight and volume loss for the beads on carbonization is about 50%, and the original unit weight of the cereals is in the order of 50 to 60 lb./cu.ft. (depending on the type of cereal). Therefore, the carbon beads have a final volume expansion or yield of approximately 18 times the original volume of the raw materials. In general the ideal size of the beads is about 1/8 inch. Larger sizes will lead to a weaker material when combined with matrices such as portland cement paste due to the "size effect" which is well known for aggregated materials. Some typical carbon beads are shown in Figure 1. These were produced from corn by expansion extrusion, and carbonization in a rotary dryer.

If a single bead of expanded carbonized wheat is broken in half, it is seen that it has a cellular structure enclosing thousands of tiny pockets of air which accounts for the very excellent insulation properties of the beads. This cellular structure is clearly shown in Figure 2 which is a scanning micrograph of the internal structure of a typical bead (courtesy Professor R. L. Berger, University of Illinois). The K factor varies according to the size of the beads, the packing and the matrix. However, typical values range from 0.2 to 0.4 B.T.U./(hr.) (ft.^{2}) (°F/in.). This value is similar to expanded polystyrene beads which have a similar cellular structure.

Since the beads are essentially carbon, they are completely inert, and are totally resistant to biological attack, most chemicals, and various fluids including water.

The beads are also highly fire resistant since the volatiles have been completely removed during distillation. In air the beads will first start to glow at a temperature in excess of about 800°F. The actual energy released during this process is extremely low since the material has a very low unit weight. For example, twenty five cu.ft. of the beads release less energy than one cu.ft. of pine lumber. It is important to note also that even this energy in the beads will only be released if the ambient temperatures are in excess of about 800°F for a reasonable period of time.

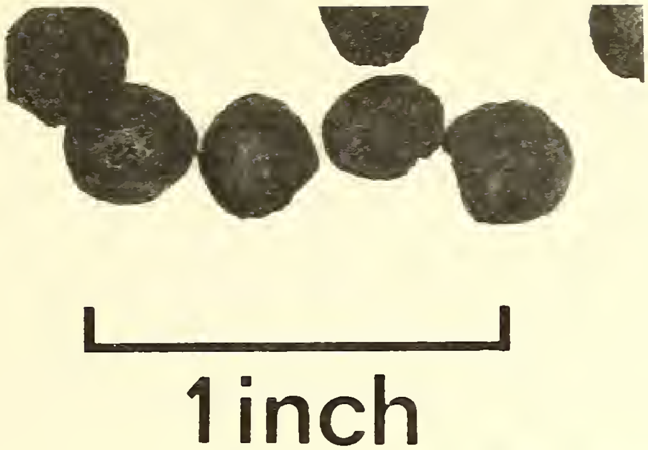


Figure 1. Carbon beads produced from corn by expansion extrusion.

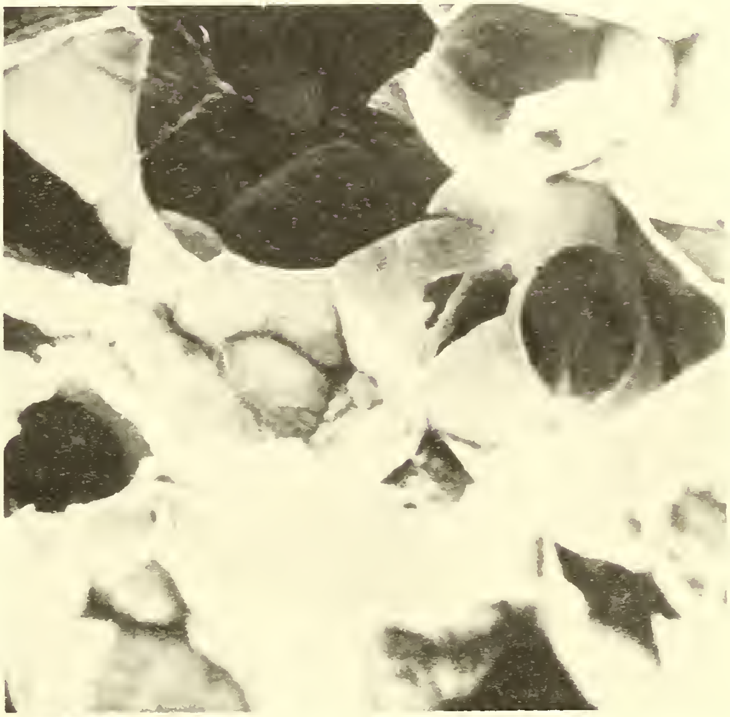


Figure 2. Microstructure of expanded, carbonized wheat bead (120x) (courtesy Prof. R.L. Berger, University of Illinois).

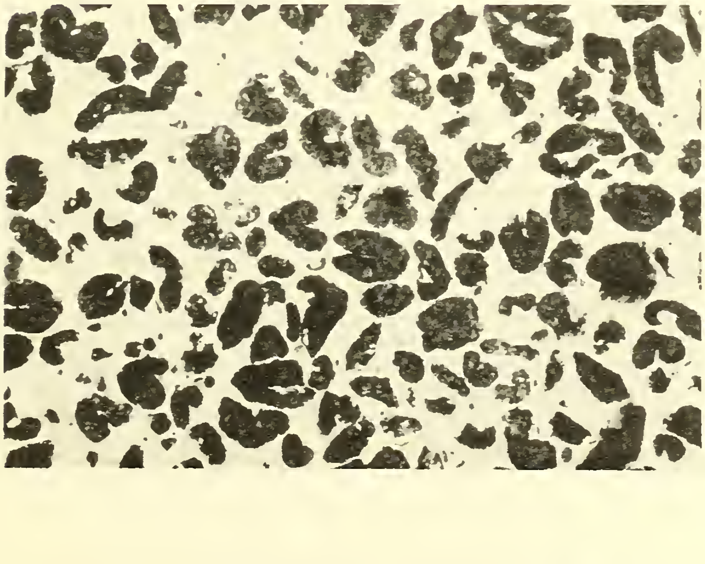


Figure 3. Insulated concrete made with carbonized wheat beads.

If the beads are embedded in a matrix such as gypsum or portland cement, they exhibit good thermal stability. Since air is excluded, the carbon cannot be oxidized and is stable to temperatures in excess of 3000°F. In fact, most matrix materials such as portland cement will disintegrate long before the carbon beads.

Immersed in water, the beads will continue to float, even after long periods of boiling, but about 1/3 of the volume of each bead becomes filled with water after long periods of time. However, many of the applications for the beads such as wall insulation, ceramics, and filters are essentially "dry". For exposed or water submerged applications, the beads must always be used in combination with a binder such as asphalt. Asphalt/bead composites are totally impervious to moisture.

Competitive Position. Typical carbon beads produced are about 1/8 inch in diameter, and have a unit weight of about 3.0 to 3.5 lb./cu.ft. This represents a volume expansion of about 18 times compared to the original cereal. Cost projections based on current cereal prices have shown that these beads can be produced for about 25¢ to 30¢ per cubic foot, and therefore would have a selling price of about 45¢ to 50¢ per cubic foot. These costs could be considerably lowered if waste products such as corn cobs were used as fillers in the starting materials and/or if the final volume expansion could be increased. Nevertheless, for purposes of this discussion, a conservative approach was used, and a projected selling price of 50¢/cu.ft. delivered was used.

The main products which carbon beads can compete with are one of two types: materials which provide insulation only (example: fiberglass wool), and materials which act as both insulators and lightweight fillers (example: vermiculite). These two separate types of products will be dealt with separately.

Table 1 provides prices and properties of various materials which are used only for insulation.

Table 1. Competitive insulation materials

Product	Typical Density (lb./cu.ft.)	Price[1/] ($/cu.ft.)	K[2/] Value	Price x K	Fire Resistance	Water Absorption
Rock wool	2.00	0.20	0.27	0.05	Excellent	High
Fiberglass wool	0.95	0.28	0.30	0.08	Excellent	High
Styrofoam	2.00	1.50	0.22	0.33	Poor	Nil
Polystyrene beadboard	2.00	1.00	0.23	0.23	Poor	Nil
Phenolic foam	3.50	1.70	0.20	0.34	Good	Low
Urethane foam	2.00	2.50	0.15	0.38	Poor	Nil
Loose carbon beads	3.50	0.50	0.25	0.13	Good	Low

[1/] Prices of all items include delivery. Shipping charges for fiberglass and mineral wool are least since these can be compressed.

[2/] K is the coefficient of thermal conductivity in (BTU) (in.)/(hr.) ($ft.^2$) (°F). A low K value indicates good insulation.

Obviously, the best insulation material is one which provides the lowest K value at the lowest price. Therefore, if we multiply the price by the K factor, the resulting number provides an indication of the efficiency or cost benefit of the material. The results of this multiplication are shown in Table 1, and it is seen that mineral wool has the greatest efficiency since its price x K factor equals 0.05. However, rock wool is rapidly being replaced by fiberglass wool since it irritates the skin, and it may therefore be discounted as a competitive product. The next most efficient material is fiberglass wool (price x K=0.08), and the carbon beads would not be competitive with this product (price x K=0.13 @ 50¢/cu.ft.). As noted earlier, this situation would change if costs can be lowered for the beads.

It is seen from Table 1 that the carbon beads have a much greater price efficiency than any of the plastic foams. For example, the carbon beads are 0.38/0.13 = 2.9 or roughly 3x as efficient as the polyurethane foam. The beads, therefore, can be used as a filler in polyurethane and phenolic foams to reduce cost. The beads can also be used as a direct replacement for the two types of polystyrene foam in many applications such as road insulation. For this application, the beads would be mixed with sand or cement paste.

Finally, it is seen from Table 1 that the carbon beads have good fire resistance and low water absorption, and these properties are useful for many applications. For example, if the beads are used as a filler in polyurethane foam, they reduce the smoke given off during a fire, and so the foam could be used for many applications where it is presently excluded because of building codes.

Table 2 below provides prices and properties of lightweight, insulating filler materials.

Table 2. Competitive lightweight insulating fillers

Product	Typical Density (lb./cu.ft.)	Price[1/] ($/cu.ft.)	K Value	Price x K	High Temperature Stability	Water Absorption
Vermiculite	7.0	0.50	0.50	0.25	Yes	High
Polystyrene beads	1.5	0.70	0.35	0.25	No	Nil
Glass nodules	2.0	1.00	0.35	0.35	No	Low
Loose carbon beads	3.5	0.50	0.25	0.13	Yes	Low

[1/] Prices include shipping in Toronto area except for glass nodules which are F.O.B. plant.

As seen in Table 2, the carbon beads have a much greater efficiency than any of the other products. For example, the beads provide about twice the insulation per unit cost as vermiculite since the price x K factor for vermiculite is 0.25 compared to 0.13 for the carbon beads. In addition, carbon beads absorb much less water than vermiculite, and this provides superior insulation. Gypsum board filled with vermiculite requires considerable drying before attaining its insulation properties, and the gypsum matrix is weakened because of the large quantities of water added to the mixture.

Carbon beads are also superior to the other fillers in many respects. For example, the glass nodules produce SO_2 gas when mixed with portland cement paste, and therefore builders are reluctant to use the nodules as insulating fillers in concrete. Carbon beads are completely inert and do not react with the cement paste. Polystyrene beads are the most common insulating filler for concrete, but these beads give off substantial amounts of smoke during a fire. Only negligible amounts of smoke are given off by the carbon beads because they are already carbonized, and so carbon beads would be favored for this application because of both lower price and superior properties. A typical insulating concrete made by combining carbon beads and portland cement mortar is shown in Figure 3. These beads were produced by carbonizing puffed wheat although, as noted earlier, extrusion expansion of small spherical beads is now preferred over puffing.

Carbon beads are also competitive with many non-insulating lightweight fillers such as veralite, which is a lightweight ceramic aggregate selling at $4.00/cu.ft. Another example is carbon microspheres, which were recently developed in Japan and sell for about $4.00/cu.ft.

It is also anticipated that new uses may be generated for the carbon beads, and numerous firms have asked for samples so they can experiment with new applications. One especially interesting potential application is to use the beads to soak up oil spills. However, this and other proposed newer applications require further investigation.

Projected Sales Volumes. This section of the paper summarizes the results of a study made for the potential sales volume in Canada. To date, studies of the U.S.A. market have not been made, but this market could be estimated roughly by the proportion of populations in each country; that is, the U.S.A. market would be approximately 10x the Canadian market. In estimating the sales volumes, a conservative approach was used in that only the most obvious uses for the carbon beads were considered, and the projected volumes were based on a selling price of the beads of 50¢/cu.ft. delivered.

As a first step in preparing estimates, the most recent production figures for various materials in Canada were obtained from Statistics Canada (Government of Canada), and are summarized in Table 3. From Table 3, it is seen that insulating wools have the unusually high annual volume of 130,000,000 cubic feet. However, these have not been included in the estimates since, as noted earlier, carbon beads will not be competitive with the insulating wools unless the industrial volume expansion is increased and/or waste fillers added.

Production figures on three other potential markets were not available from Statistics Canada, and were obtained from other sources.

Table 3. Annual Canadian production volume

	Material	Year Reported	Quantity (x 10^3)	Unit of Quantity	Volume[1/] (x 10^3 cu.ft.)
1.	Concrete blocks (gravel aggregate)	1971	172,000	8" x 16" blocks	77,000
2.	Concrete blocks (lightweight aggregate)	1971	35,300	8" x 16" blocks	16,000
3.	Concrete bricks	1971	109,500	single bricks	10,000
4.	Refractory bricks	1970	140	tons	2,000
5.	Gypsum wallboard	1971	1,077,000	square feet	45,000
6.	Expanded vermiculite	1969	7,500	cubic feet	7,500
7.	Expanded perlite	1968	800	cubic feet	800
8.	Lightweight aggregate	1968	300	tons	4,200
9.	Polystyrene foam	1971	34,000	pounds	17,000
10.	Insulating wools	1971	550,000	square feet	130,000

[1/] Calculated from known properties of materials.

(1) Rigid polyurethane foam. These foams are almost exclusively used for insulation, and must be distinguished from flexible polyurethane foams which are used for cushions, etc. Unfortunately, Statistics Canada will not release production data on the rigid polyurethane foams. Therefore, several urethane foam suppliers were contacted in the Toronto area and, using their figures, the total Canadian production was estimated to be 2,500,000 cubic feet. It is possible to replace about 50% of the volume of the foam with beads and this reduces the cost and increases the fire resistance of the foam. Therefore, the potential annual volume is 1,500,000 cubic feet.

(2) Prefabricated concrete panels. Almost every new office and industrial building in Canada is now clad with prefabricated concrete panels, but this is a recent development, and Canadian production figures are not yet available from Statistics Canada. Therefore, the Ontario Precast Concrete Manufacturer's Association in Toronto was contacted to obtain an estimate. This organization reported that in their opinion, the Canadian annual volume of concrete panels was about 13,000,000 square feet, and was growing very rapidly. Since the panels are about 6 inches thick, this gives an annual volume of 6,500,000 cubic feet. For all types of panels, carbon beads can be mixed with cement paste, and incorporated in the panel as the core to give a sandwich panel which is lighter, less expensive, and provides insulation. The majority of the panels now being produced incorporate a layer of polystyrene foam as a core, and the carbon beads would be favored over the foam because of lower cost and improved fire resistance. Normally, the insulating core represents about 50% of the volume of the panels so the potential annual volume of carbon beads is 0.5 x 6,500,000 = 3,250,000 cubic feet for Canada.

(3) Highway insulation. Estimates for highway insulating materials are also not available from Statistics Canada. However, it is known that in excess of 1,000,000 board feet of styrofoam was used in Ontario (source is Transportation Development Agency, Ministry of Transport, Federal Government). Apparently, this volume has increased rapidly each year. However, because of the high price of styrofoam (Table 1), it is usually only used in trouble spots on highways where excessive frost heaving has occurred.

Carbon beads can be mixed with gravel to provide an insulated base, or can be mixed with cement paste to provide a rigid foundation. Insulating concretes made from polystyrene beads and cement paste are already being used extensively in Europe, and have now been introduced to the Toronto area. Carbon beads have a much lower cost than styrofoam or polystyrene beads, and so will replace these materials directly. In addition, it is expected that the carbon beads will replace gravels in many urban areas where gravel must now be shipped in from distant points. A one-inch-thick layer of carbon beads provides approximately the same insulation as 12 inches of gravel, and gravel can cost as much as $0.30/cu.ft. in urban areas.

Although records are not available, it is estimated that several hundred miles of roads are built in Ontario each year for new subdivision developments, and most of these subdivisions are in ubran areas where gravel shortages exist. Rough calculations show that about 1,000,000 cubic feet of carbon beads could be used for every 20 miles of two-lane road. A conservative estimate of the potential maximum annual volume is 120 miles or 6,000,000 cubic feet of beads for Ontario, or roughly 20,000,000 for Canada.

It can also be argued that additional beads will be needed for insulated bases for the new commuter trains which will be built in areas where gravel shortages exist. In fact, the European experience has been that polystyrene insulated concretes provide a much better base for these newer trains than gravels because of the vibrations. As noted earlier, carbon beads would be favoured over polystyrene beads in insulated concretes because of lower cost.

It is now possible to estimate a maximum potential annual volume for Canada. Referring to Table 3, it can be argued that the carbon beads could be used as a filler for the first six types of materials to provide insulation, and would occupy about 50% of the volume. This calculation has been carried out, and the volumes are given in Table 4 for items 1 to 6 inclusive. Carbon beads could directly replace materials 7 to 10 in Table 3 and so the volumes in Table 4 for these items are the same. The volumes for the remaining items are entered directly from the preceding calculations.

Table 4. Estimated maximum annual volume of carbon beads for Canada

	Application	Annual Canadian Volume (x 10^3 cu.ft.)
1.	Filler for concrete block (gravel aggregate)	38,500
2.	Filler for concrete block (lightweight aggregate)	8,000
3.	Filler for concrete bricks	5,000
4.	Filler for refractory bricks	1,000
5.	Filler for gypsum board	22,500
6.	Replace vermiculite	7,500
7.	Replace perlite	800
8.	Replace lightweight aggregate	4,200
9.	Replace polystyrene foam	17,000
10.	Filler for polyurethane foam	1,500
11.	Core for panels	3,250
12.	Highway insulation	20,000
Total Estimated Volume (cubic feet x 10^3)		130,000 (rounded off)

In conclusion, there is a maximum potential annual volume of 130,000,000 cubic feet for Canada. In practice, the actual volume will be much less since a total replacement would never occur. However, taking into account the fact that the building construction rate doubles about every 10 years, it is not unrealistic to expect that the annual sales volume in Canada could reach 50,000,000 cubic feet within 10 years after plants had been constructed and development had been completed. For example, if the carbon beads were used as a filler for only one half the production of gypsum wallboard, this would create an annual market of 11,250,000 cubic feet alone based on 1971 figures (see Tables 3 and 4). The presence of the beads in gypsum reduces the weight and increases the fire resistance due to its greater insulation properties. Also, if the price of the beads could be reduced, this would allow penetration of the insulating wool market which is 130,000,000 cubic feet by itself based on 1971 figures.

Social and Economic Significance. In commercial production and based on present processes, 1 cubic foot of carbon beads can be produced from 3 pounds of cereals including waste products if added. Using the figure of 50,000,000 cubic feet annual production given in the preceeding section as a guide this represents an additional annual cereal market of up to 150,000,000 pounds for Canada, and approximately ten times this amount for the U.S.A. It is important to note that all types of grains can be used to produce insulating carbon beads. Spoiled or waste grain, and low grade grains are also suitable. Therefore, this will avoid a total loss of a spoiled crop, and will also allow farmers to seed areas of their farms which have been formerly unproductive due to low protein levels of the grain produced in these areas.

There are also sociological implications for the development. Research on expanded carbonized grain has been conducted against the background of two major crises which are facing the twentieth century. The first is the increasing necessity for conserving energy. This has resulted in the recent decree by U.S. President Richard Nixon that all new Federal buildings, including housing, must observe low energy consumption principles, meaning primarily greatly improved insulation. That this is not simply a political gesture was brought out by the closing, in January, of schools in the U.S. mid-west because they could not be heated. The second is the rapid depletion of all the world's natural resources. A dramatic result of this is the necessity in Europe, of already having to build new roads on foundations of insulating concrete, in which 2 inches of concrete replaces 12 inches of gravel, because of exhausted gravel supplies. It is emphasized by the continued public demand for re-cycling almost every non-replenishable material, regardless of the economics of doing it.

Millions of dollars are currently being spent annually to develop more efficient, more economical insulating materials to meet the urgent necessity for conserving energy and to obtain an increasing share of the expanding market. All the commercial insulating materials presently in use or being developed, however, are non-replenishable materials. Many are derivatives of the petroleum industry and so only aggravate the energy crisis they are supposedly seeking to solve. Carbon beads have the advantage of being based on cereals and organic wastes which are renewable resources since they can be grown each year, and their low projected production costs indicate that they can provide low cost insulation to conserve energy.

Summary of Advantages. Insulated carbon beads can be produced for about 50¢/cu.ft. compared to competitive products such as expanded polystyrene beads which are about 70¢/cu.ft., glass nodules at $1.00/cubic foot, and expanded vermiculite at $0.50/cu.ft. In addition to this price advantage, carbon beads have various other advantages related to their properties as follows:

1. Carbon beads are non-elastic and do not deform easily as is the case with expanded polystyrene beads. This feature makes it possible to compact a mixture of carbon beads and portland cement paste into a mould. The brittle beads do not spring back, as is the case with a mixture of polystyrene beads and cement paste; and so good volume control is realized in the production of, say, insulated concrete blocks.

2. Unlike expanded vermiculites and perlites, expanded carbonized beads do not readily absorb water during mixing with portland cement paste or gypsum paste. This creates a superior product in that less drying is required before full insulation is achieved, and the carbon beads are less susceptible to absorption of hygroscopic (air borne) moisture which can lead to a reduction of insulation.

3. Unlike organic insulators such as expanded polystyrene beads, styrofoam, and urethene foam, carbon beads generate only small amounts of smoke and heat in a fire (most of the smoke and heat has already been released during carbonization). Therefore, carbon beads could be used in building components subject to fire. Carbon beads also have a higher thermal resistance than organic insulators; that is, they remain stable up to much higher temperatures. This allows their use in applications such as insulating fillers in concrete blocks which must be autoclaved at higher temperatures.

4. In applications where air or oxygen is not accessible to the carbon beads, as is the case when the beads are encased in a refractory cement, the beads are stable to refractory temperatures making possible their use as insulating fillers for refractory products such as bricks.

5. Most loose insulating fillers such as fiberglass wool and expanded vermiculite pack down in a wall with time and therefore lose part of their effectiveness as insulators. Carbon beads have good volumetric stability and will not pack down.

6. The final advantage is that carbon beads are based on renewable resources.

Concluding Remarks. The laboratory experiments and costing studies which have been carried out appear to be quite promising, and so a further development program has now been undertaken as follows. As a first step, a small production facility is presently being set up in Toronto to produce sufficient quantities of carbon beads to supply to numerous potential end users who have requested samples. If their test programs verify the potential of the beads, as expected, then the process will be commercialized by setting up a prototype production plant. Concurrent with these activities, research will be continued on the basic process. For example, it is important to explore the use of adding organic waste products to the cereals to reduce costs.

Acknowledgments

The author is indebted to Mr. M. Dennis, President TDR Engineering Development, Ltd., Toronto, for allowing various data to be published in this paper and to Drs. E. I. Robinsky and J. Timusk for their many helpful suggestions.

Literature Cited

1. Robinsky, E. I., Timusk, J. and Riley, V. R. Composite lightweight construction and insulating materials comprising expanded natural grain. Ger. Offen. 2,136,117 (1972).

2. Wilson, H. S. Development of low-density material through carbonization of puffed wheat. Mines Branch Report IR 72-29, Department of Energy, Mines and Resources, Ottawa, June 1972.

FLAVOR CONTRIBUTIONS AND CHARACTERISTICS OF RAW AND PROCESSED WHEAT FRACTION COMPONENTS

J. A. Maga and K. Lorenz
Colorado State University
Department of Food Science and Nutrition

It is generally assumed that the characteristic organoleptic properties of wheat-based bread is due primarily to the changes that take place in the product as the result of the formulation, fermentation, and baking sequence. However, an area that is frequently overlooked as a source of flavor precursor materials, as witnessed by the scarcity of data published, is the wheat itself. The influential role of wheat on bread flavor can be appreciated by the fact that a portion of the aroma and flavor of bread can be described as being wheaty (1).

From a compositional standpoint wheat contains numerous flavor reactive compounds, many of which may be present in only trace amounts. Thus, it is the primary purpose of this review to discuss the role of wheat components on the flavor properties of bread.

Gross Compositional Relationship of Wheat to Flavor. Of special interest in relation to flavor is the role of protein, moisture, fat and starch. In the protein fraction short chain peptides, which have been reported to be astringent and bitter, along with free amino acids, which are highly reactive, can be found. The role of moisture in certain nonenzymatic browning reactions that can occur with storage is also important. Crude fat, which includes unsaturated and free fatty acids, is another important flavor precursor source. Likewise, the starch fraction, which contains reactive carbohydrates such as reducing sugars, makes a definite contribution to final bread flavor. The specific roles of individual classes of compounds within these groups will be discussed in detail in a later portion.

Influence of Milling. As we are all aware, milling can concentrate certain compositional fractions. A prime example would be the higher levels of protein and fat in wheat germ as compared to the whole grain. Thus, in a product like wheat germ, although natural antioxidants may be present, we have a situation whereby highly reactive flavor constituents are concentrated and thus the flavor stability of wheat germ is affected.

Role of Lipids. In the case of lipids two particular types will be discussed. The first involves the role of unsaturated fatty acids on flavor. From Table 1, it can be seen that unsaturated fatty acids comprise approximately 72% of total wheat lipids.

Table 1. Fatty acid composition of wheat lipids (2)

Fatty Acid	Chain Length	%
Myristic	C-14:0	0.1
Palmitic	C-16:0	24.5
Palmitoleic	C-16:1	0.8
Stearic	C-18:0	1.0
Oleic	C-18:1	11.5
Linoleic	C-18:2	56.3
Linolenic	C-18:3	3.7
Arachidic	C-20:0	0.8
Other	--	1.1

Due to their unsaturation these lipids are less stable upon storage and processing. Their breakdown produces carbonyls which can significantly contribute to flavor or serve as precursors for other flavor related compounds.

The second class of lipids to be discussed is free fatty acids. As can be seen from Table 2 these can be naturally occurring or form upon storage or processing due to the breakdown of triglycerides. Data presented in Table 2 demonstrates that room temperature storage for four months approximately doubled the amount of free fatty acids found in wheat flour. Thus, free fatty acids, especially of the characteristically flavored shorter chain varieties, can also influence the flavor of wheat based baked products.

Role of Carbohydrates. Most of the carbohydrate material in wheat is in starch forms. However, a small fraction does occur in more flavor reactive forms such as glucose, fructose, sucrose, and maltose (Table 3). Average reported taste threshold values for several of these sugars are also included to demonstrate their contribution to the flavor of wheat flour itself.

Table 2. Changes in lipid composition of wheat flour as influenced by storage (3)

Lipid Class	Conditions -20°C Control	 15°C 6 months	 25°C 4 months
	mg/100g flour		
Triglycerides	162	89	94
Diglycerides	97	126	119
Monoglycerides	20	50	37
Free Fatty Acids	76	159	144

Table 3. Reactive carbohydrates reported in wheat flour (4)

Carbohydrate	Reactive Amount (%)	Taste Detection Threshold in Water (5)
		g/100 ml water
Glucose	0.04	0.4
Fructose	trace	0.15
Maltose	trace	1.37 (6)
Sucrose	0.27	0.3
Raffinose	0.17	--

The role of reducing sugars in the formation of bread flavor is well documented but it should be remembered that wheat itself can act as a partial source of these flavor precursors.

From Table 4 it can be seen that certain carbohydrates can be quite active during storage probably with regard to non-enzymatic browning reactions.

Table 4. Changes in carbohydrates in stored wheat (7)

Carbohydrate	Zero Time Control	Conditions -- 8 weeks, 30°C Air	 Nitrogen	 Carbon Dioxide
		mg/10 g of wheat		
Glucose	8	7	24	23
Fructose	6	5	18	16
Galactose	2	3	9	9
Maltose	5	1	4	3
Sucrose	54	21	39	36

By comparing the air and nitrogen storage conditions it can be seen that the nitrogen protected the reactive carbohydrate but in an air atmosphere the levels of these reactive carbohydrates decreased due to their participation in the formation of additional flavor compounds.

Role of Proteinaceous Materials. As mentioned in the introduction, peptides and free amino acids are protein components that can have an influential role in the flavor of wheat. The primary role of free amino acids is as flavor precursors in the formation of numerous volatile compounds. This can best be appreciated by viewing the data summarized in Table 5. As fermention proceeds the level of most free fatty acids decreases due to their reactive nature. As can also be seen few free amino acids remain in the crust of the bread as compared to the crumb. At this stage, the majority of the free amino acids have participated in non-enzymatic browning reactions. Thus, free amino acids in the original flour serve as a natural source of flavor precursor material.

The exact contribution of short chain peptides on bread flavor has not been documented. However, one would expect that certain of these peptides are naturally present in wheat and that their level would increase with fermentation.

Table 5. Free amino acids concentrations during phases of bread production (8)

Amino Acid(s)	Flour	Unfermented Dough	Fermented Dough	Crumb	Crust
			micromoles/100 g dry basis		
Alanine	14.34	86.98	22.94	29.05	2.12
Arginine	2.11	6.66	15.30	11.43	trace
Aspartic acid	14.17	60.53	14.91	10.92	0.83
Cystine	0.56	3.25	1.16	1.01	trace
Glutamic Acid	8.85	71.85	46.83	51.39	1.13
Glycine	4.08	11.74	10.43	12.43	0.84
Histidine	0.95	---	---	---	---
Isoleucine	4.13	6.60	1.58	3.07	0.52
Leucine	5.54	8.66	1.73	4.79	0.27
Lysine	2.39	32.31	25.53	12.76	trace
Methionine	0.69	2.11	0.95	1.83	trace
Phenylalanine	3.31	5.86	0.18	1.95	1.64
Proline	4.66	21.65	17.11	11.21	0.44
Serine & threonine	27.50	68.14	19.22	22.88	1.24
Tryosine	3.12	5.99	0.49	1.09	--
Valine	6.83	16.15	4.60	6.41	0.62

Role of Naturally Occurring Volatiles. Considering the role of cereal grains in the world food economy, relatively few studies have been reported on their flavor composition. The data summarized in Table 6 represents published information dealing specifically with wheat flour.

Table 6. Volatile compounds reported in wheat flour (9,10)

Compound Reported in Flour	Found in Bread ? (11,12)	ppb Odor Threshold in Water(13)
Carbonyls		
Ethanal	yes	5.0[1]
Propanal	yes	9.5
Butanal	yes	9.0
Isobutanal	yes	0.9
Pentanal	yes	12.0
Isopentanal	yes	0.15
Hexanal	yes	4.5
Heptanal	yes	3.0
Octanal	yes	0.7
2-butenal	yes	525
Phenylacetaldehyde	yes	5.0[1]
Propanone	yes	270,000[1]
Butanone	yes	---
3-methyl-2-butanone	--	---
2,2-dimethyl-3-pentanone	--	---
2,3-butanedione (diacetyl)	yes	2,700[1]
Cyclopentanone	yes	---
Alcohols		
Methanol	--	---
Ethanol	yes	35,900[1]
Amyl alcohol	yes	---
Isoamyl alcohol	yes	---
Esters		
Ethyl acetate	--	5,000[1]

---

[1] Average of odor threshold values reported in compilation by Stahl (6).

As can be seen the majority of the compounds found in wheat flour have also been reported to be present in bread, thus it can be concluded that much of the flavor of bread originates from volatile components present in the original wheat and that procedures such as fermentation and baking just serve as means of increasing the levels of such compounds. The absolute contribution to flavor of these volatile compounds found in wheat has not been documented since no quantitative data are currently available. This lack of data is primarily due to the facts that reproducible techniques for quantitating volatile compounds are somewhat lacking and that the volatile composition of wheat is continually changing due to the reactive state of lipids, carbohydrates, and proteins. However, some appreciation for the possible contribution of volatile wheat flavor components can be obtained by observing the reported odor thresholds for some of the compounds in question.

Role of Phenolic Constituents. Phenolic acids have been reported in wheat grain (14), wheat flour (15), washed wheat gluten (16) and wheat germ (17), and based on their taste thresholds (18) and amounts present in wheat flour (19) they can significantly contribute to astringency in wheat flour. Steinke and Paulson (20) have reported that the heating of corn increased the amount of free phenolic acids. Thus, it is postulated that upon baking the level of free phenolic acids may increase and as a result contribute to the astringent background flavor of bread.

Role of Pyrazines. Pyrazine compounds have been generally characterized as possessing typical toasted and nutty flavors and their presence and levels in American white bread has been reported (21). Their occurrence in bread may arise from two primary pathways. The most probable is their formation through the interaction of free amino acids and sugars which, as discussed previously, are naturally present in wheat. Secondly, they may be naturally occurring in wheat in trace quantities and due to their extremely low odor thresholds and/or to their ability to serve as precursors for additional pyrazine compounds can significantly contribute to desirable bread flavor. To date detection and quantitation in wheat has not been reported but it is postulated that they are present especially in wheat that has undergone extended storage.

Conclusions. The flavor of bread is quite complex, but the chemical composition of wheat is also complex and thus, can serve as the source for many of the flavor compounds reportedly found in bread.

Literature Cited

1. Caul, J. F. and Vaden, A. G. Bakers Digest 46(1): 39, 1972.
2. Nelson, J. H., Glass, R. L. and Geddes, W. F. Cereal Chem. 40: 337-343, 1963.
3. Clayton, T. A. and Morrison, W. R. J. Sci. Fd. Agric. 23:721, 1972.
4. MacKenzie, R. M. Soc. Chem. Ind. Monograph, No. 3, 1958.
5. Berg, H. W., Fillipello, F., Hinreiner, E. and Webb, A. D. Food Technol. 9:23, 1955.
6. Stahl, W. H. Compilation of odor and taste threshold values data. Amer. Soc. Testing Materials, No. DS48, 1973.
7. Lynch, B. T., Glass, R. L. and Geddes, W. F. Cereal Chem. 39:256, 1962.
8. El-Dash, A. A. Bakers Digest 45(6):26, 1971.
9. McWilliams, M. and Mackey, A. C. J. Food Sci. 34:493, 1969.
10. Hougen, F. W., Guilliam, M. A. and Curran, W. A. J. Agr. Food Chem. 19(1):182, 1971.
11. Collyer, D. M. Bakers Digest 38(1):43, 1964.
12. Coffman, J. R. Bread Flavor. IN: Chemistry and Physiology of Flavors. Edited by: Schultz, H. W., Day, D. A. and Libbey, L. M. AVI Publishing, Westport, Conn. 1967.
13. Guadagni, D. G., Buttery, R. G. and Okano, S. J. Sci. Fd. Agric. 14:761, 1963.
14. El-Basyouni, S. and Towers, G. H. N. Can. J. Biochem. 42:203, 1964.
15. Gallus, H. P. C. and Jennings. Aust. J. Biol. Sci. 24:747, 1971.
16. Gallus, H. P. C. and Jennings. Aust. J. Biol. Sci. 24:825, 1971.
17. King, H. G. C. J. Food Sci. 27:446, 1962.

18. Maga, J. A. and Lorenz, K., Cereal Sci. Today, In Press, 1974.

19. Maga, J. A. and Lorenz, K. Cereal Sci. Today 18(9):306 (Abs.), 1973.

20. Steinke, R. D. and Paulson, M. C. J. Agric. Fd. Chem. 12:381, 1964.

21. Sizer, C. E., Maga, J. A. and Lorenz, K. J. Food Sci., In Press, 1974.

PRECURSORS OF BREAD FLAVOR

John A. Johnson
Department of Grain Science and Industry
Kansas State University

This is a review of how bread flavor is created. During the 4-hour fermentation normally used for making bread, the yeast produces ethyl alcohol, carbon dioxide, and carbonyl compounds. Bacteria are responsible mainly for producing short-chain organic acids. Also because enzymes are added or elaborated by the organisms, maltose, glucose, peptides, and free amino acids are formed. During baking many of the compounds produced in fermentation may be volatilized while the amino acids and sugars react to form new odoriferous carbonyl compounds and complex polymers. There is also some sugar caramelization. The creation of bread flavor is then complete. A new baked product process that calls for adding amino acids and organic acid salts in certain ratio as found in dough after 4 hours of fermentation eliminates the need for primary fermentation. Physical characteristics and consumer preference of breads made by the new process are equal or superior to those of breads made by the conventional sponge-dough process.

Man has enjoyed bread as the mainstay of his diet for more than 8000 years. History indicates that fermentation was discovered in Egypt and that in the courts of Pharaoh, bread making was assigned to certain groups. The flour was mixed with water and an old piece of dough, which served as a source of yeast and other microorganisms for fermentation. Years later, primarily due to the work of Pasteur, fermentation was ascribed as a function of yeast.

During the past two decades, our knowledge of fermentation has grown in great detail. We know the pathway of sugar metabolism by yeast and many other microorganisms. Bakers of bread need be concerned only about the end-products of fermentation. The end-products also have been well characterized in the past decade. The broad classification of compounds resulting from dough fermentation are summarized in Table 1.

Table 1. Compounds produced in a bread dough by fermentation.

Ethyl alcohol	Organic acids	Glucose
Carbon dioxide	Ethyl esters	Peptides
Carbonyls	Maltose	Amino acids

The main end-products of yeast metabolism are ethyl alcohol and carbon dioxide. Minor amounts of carbonyl compounds are produced as a result of nitrogen metabolism. Many of the compounds produced in fermentation are lost to the air during extended fermentation and subsequent mixing and baking at elevated temperatures. Small amounts of fusel oils are produced also by the yeast. Specific bacteria produce a series of short-chain organic acids as a result of their metabolism. The organic acids react with ethyl alcohol to create a series of ethyl esters. In addition to the metabolic products, soluble starch of the flour is converted to maltose and the gluten protein is partially converted to soluble peptides and free amino acids. Maltose contributes to the final sugar content of the bread. These reaction products form the precursors of flavor which is only complete after the baking process.

Of the many compounds produced in a fermenting dough, the more volatile ones are concentrated in the gas oven vapors. Thus, we find alcohol, esters, carbonyl compounds, carbonic acid and water in the oven vapors. Trace amounts of some of the compounds are found in the bread crumb but the carbonyl compounds are most heavily concentrated in the bread crust. The bread crumb contains fair concentrations of unreacted amino acids and monocarboxylic organic acids. Maltose and glucose, readily metabolized by yeast, are present when dough is baked only if surplus sugar is added to the formula.

Reactions that occur during baking, almost exclusively in the crust, are finally responsible for creating bread flavor and aroma. The reactions are primarily between reducing sugars and free amino acids. Pyrolysis of sugars also contributes to the aroma and taste. If the dough after rising in the pan, has organic acids, ethyl alcohol, ethyl esters, carbonyl compounds, carbon dioxide, free amino acids, and reducing sugars, the voaltile compounds will be mainly distilled away while the organic acids, higher molecular weight alcohols, amino acids, and sugars remain. The free amino acids react with the reducing sugars during baking to form a new series of odoriferous carbonyl compounds. At the same time large complex polymers are formed as a result of condensation reactions of the furfural and aldehyde compounds. Thus, bread flavor results from a complex series of compounds. The type and concentrations of the amino acids mainly control bread aroma while taste is a function of sweetness, saltiness, sourness, and bitterness. The sweetness and saltiness are controlled by formulation; while sourness is a function of bacterial metabolism and bitterness is created partly by pyrolysis and polymerization reactions occurring during baking.

Current Bread Processes. Let us briefly review methods of baking now used in the United States; they are summarized as a time function in Figure 1. The sponge stage of the sponge-dough process requires about 2 minutes mixing of a total mixing time of 10-14 minutes. The sponge is given a normal 4-hour fermentation followed by addition of remaining ingredients, a remix of 10-12 minutes, then 15 minutes of floor time, then divided and given a 10-minute overhead proof before moulding. The dough is allowed to rise in the pan for 50-55 minutes and then baked for 18 minutes, so total time required is 5 hours and 45 minutes. The sponge-dough process accounts for approximately 60% of total bread production in the United States. The continuous-mix process was introduced about 15 years ago and accounts for approximately 35% of total bread production. It starts with fermentation of a broth for 3 hours before being pumped to the incorporator where other ingredients are added and then the dough is pumped to the mixer head. Here mixing time is for only a few seconds. The dough is panned directly and given a normal 50-55 minutes of proof before baking for 18 minutes. The total time used is approximately 4 hours. There has been a trend toward including up to 50% flour in the broth fermentation because without the flour in the broth, the bread is very bland and the flavor is different from sponge-dough bread, which consumers have come to expect. In the old straight dough method all ingredients are mixed in a single mix, the dough is then fermented, divided, rested, moulded, proofed, and baked for 18 minutes. The total time is about 4.5 hours.

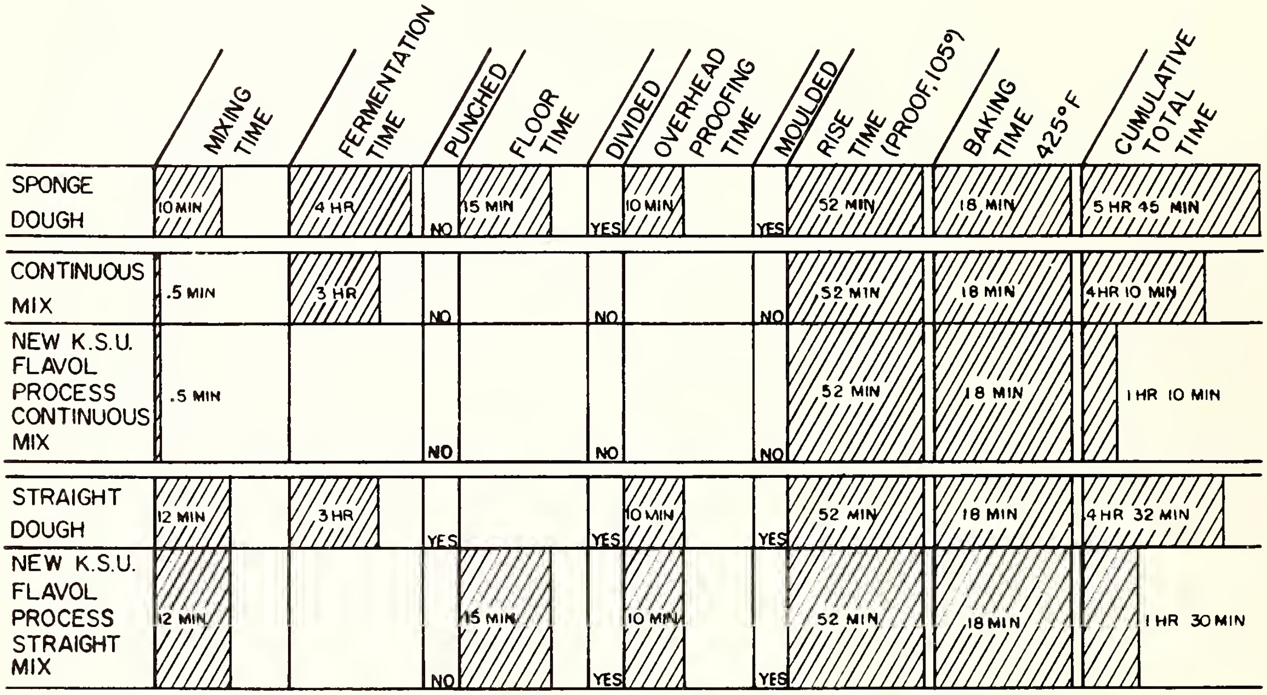


Figure 1. Average time required for operation of indicated baking procedures.

Flavol Short-Time Dough Processes. Several short-time dough processes have been introduced in recent years. Among them, is a new process to eliminate primary fermentation and at the same time control intensity of the bread flavor, named, the Flavol process; it calls for small additions of amino acids and organic acid salts in the ratio found in a dough after 4 hours of fermentation. It eliminates the lengthy primary fermentation step and, thus, greatly reduces production time while still controling intensity of bread flavor. The total time in continuous mix using Flavol ranges from 70 to 80 minutes for bread production.

The Flavol process can be applied to the straight dough method with primary fermentation eliminated. The total time ranges from 80 to 90 minutes.

The Flavol process has been used in 18 commercial bakeries for all types of baked products. The ingredients of Flavol have been approved by the Food and Drug Administration in Washington, D.C. Temporary permits have been granted for use of the process in bread shipped in interstate commerce.

White pan bread is the largest single sales item produced by the United States baking industry. Figure 2 illustrates and compares the appearances of bread made with 0.2 and 0.4% Flavol with bread made by the sponge dough process. Comparisons of loaf volume, grain, and texture have shown that the processes produce almost identical bread. American rye bread, French hearth bread and dinner rolls made by the Flavol process were equal in physical characteristics to the conventional products.

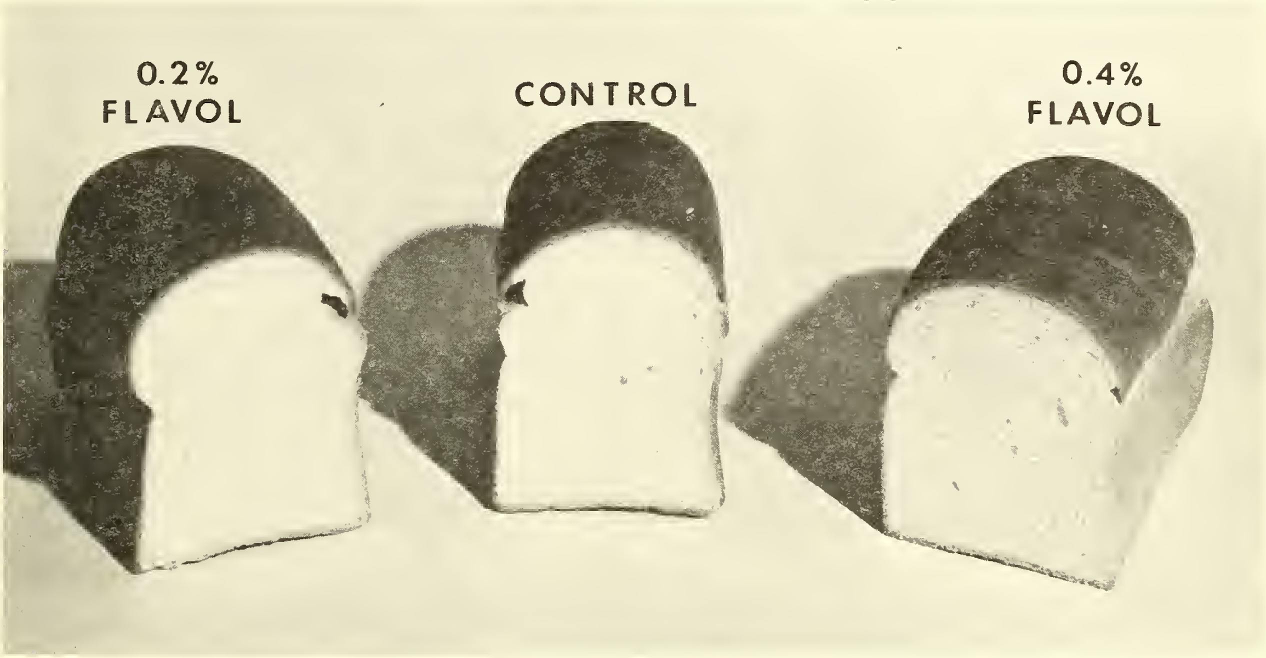


Figure 2. White pan bread made by Flavol and sponge-dough processes. No differences are apparent.

Perhaps more important than physical characteristics of the bread are flavor and consumer acceptance. To measure flavor acceptance, we selected 16 semi-trained judges and compared various breads made by conventional sponge-dough process with that made by the Flavol non-fermentation process. We asked the judges to score the bread on 3-point scales for sweetness, sourness, over-all flavor, and over-all aroma. The data for baked products using 0.2% Flavol based on flour weight are summarized in Table 2. The data are the averages of 16 judges who tested the bread in triplicate. When differences in any characteristic were significant, least significant mean differences were calculated. Most breads were scored as nonsignificantly different but French and American rye breads made with 0.2% Flavol and no fermentation time were judged superior. No type of bread made by Flavol process scored lower than the sponge-dough process bread.

Table 2. Results of consumer preference tests comparing conventional sponge-dough baked products with products made with flavor precursors and no-fermentation.

Type bread	Sweetness	Sourness	Over-all flavor	Over-all aroma
White pan bread				
Sponge-dough	1.67	1.94	1.94	1.94
0.2% Flavol, no-fermentation	1.94	2.11	1.94	2.22
0.4% Flavol, no-fermentation	2.06	2.06	2.22	1.83
L. S. D. 0.05 1/	-	-	-	-
French bread				
Sponge-dough	1.62	2.00	1.92	1.96
0.2% Flavol, no-fermentation	2.20	2.25	2.41	2.38
0.4% Flavol, no-fermentation	2.13	1.75	1.75	1.67
L. S. D. 0.05 1/	0.39	-	0.37	0.35
American rye bread				
Sponge-dough	2.00	1.89	1.89	1.83
0.2% Flavol, no-fermentation	2.44	2.49	2.50	2.28
0.4% Flavol, no-fermentation	1.56	1.67	1.61	1.89
L. S. D. 0.05 1/	0.54	0.57	0.51	-
Dinner rolls				
Sponge-dough	1.80	2.00	2.05	2.15
0.2% Flavol, no-fermentation	2.38	2.10	2.15	2.35
0.4% Flavol, no-fermentation	1.90	1.90	1.80	1.50
L. S. D. 0.05 1/	-	-	-	0.50

1/ Data without LSD indicated did not differ significantly.

THE STATUS OF HIGH-PROTEIN BREAD

J. A. Shellenberger
Grain Marketing Research Center, Agricultural Research Service
U. S. Department of Agriculture

Judging by the numerous articles appearing on the subject of high-protein baked products, it could be assumed that protein-fortified bread is an item of unprecedented expanding commercial importance. However, the impact of high-protein bread production has scarcely changed bread production or consumption patterns anyplace in the world. Bread fortified with protein supplements has been on the market throughout Europe and North America for some time, but sales have remained relatively small compared to conventional bread; and presently there seems to be no tendency for the sale of this type of specialty breads to increase relative to total bread consumption. Among national programs, apparently only the Governmnet of Israel has a requirement that all flour for bread be protein-fortified with soy flour -- but only at the 2.5% level. India and other governments have experimented with protein additives to baked products generally at levels below that required to qualify as high-protein bread.

Much of the publicity associated with the concept of high-protein bread production has been based on the anticipated sale to government food agencies of relief shipments for developing countries (7). Such sales provide an opportunity to sell high-protein supplements and special additives needed to produce satisfactory baked products when soy flour and protein concentrates in substantial amounts are added to normal wheat flour dough. The nutritive advantages of protein-fortified bread have been well known and recognized fully for a long time and this aspect has not been neglected in recent considerations, but experience has shown repeatedly that it is difficult to sell nutrition to the public. Public reluctance to accept a new food is usually avoided if a government-sponsored supply (adjusted for nutritional balance) is made available.

There appears to have been a tendency in reports to overstate the protein deficiency situation in developing countries. Based on FAO estimates and projections for the years immediately ahead, there is an adequate supply of protein for human consumption (1,19). This does not mean that inadequate distribution, lack of purchasing power, and cultural practices will not result in protein malnutrition among children, especially in lower income families. Therefore, efforts to improve the quality and quantity of proteins in bread and other baked products are desirable. Bread with higher protein content than normal can be made in several ways such as from flour of higher-than-normal protein content, by adding milk solids, vital gluten, or adding protein concentrates such as soy flour.

High-protein Bread Defined. High-protein bread is legally defined in several countries as bread containing a minimum of 22% protein, dry basis, or approximately 15% on an as-is moisture basis. Normal bread has a protein content of approximately 9%. Historically, all sorts of food materials have been added to bread, principally to extend wheat flour use but also sometimes to improve nutritional value, taste, flavor, or color. In the United States the term high-protein bread tends to be defined as the level of supplementation where an additive is required to obtain optimum baking response. Karl Finney (4), in 1946, showed that as much as 8% soy flour could be incorporated into a dough without affecting bread acceptability when a strong wheat flour was used and the baking formula contained shortening, milk solids, and adequate oxidants. Thus, for 27 years it has been well known that the nutritional value of bread could be readily enhanced without resorting to the use of special formulae, modified shop practices, or the use of additives; yet commercially that fact has had but slight impact on bread production anywhere in the world. One reason is because the cost of producing high-protein bread necessitates a higher selling price, and customers are not inclined to pay more for bread that looks, tastes, and smells no different than less expensive bread. During the past few years many articles and several international meetings have dealt with the subject of high-protein bread production (3,9,12,13,16,22,23, 24). Much scientific information has accumulated covering all phases of bread production, including evidence that various surface active compounds (surfactants) profoundly alter dough properties and bread quality.

The Use of Additives. Calcium and sodium stearoyl-2-lactylate, among the many compounds studied and tested for use by the baking industry, are fatty acid esters known to affect flour protein structure, to increase mixing tolerance, and to improve bread quality. The calcium compound, investigated in 1953, was described in 1954 (22), and marketed commercially in the baking industry by the C. J. Patterson Company, Kansas City, Missouri, under the trade name of Verv. The patent issued to Thompson and Buddemyer in 1957 was assigned originally to the Paniplus Company, Kansas City, Missouri. Calcium and sodium stearoyl-2-lactylate have been widely studied as bakery ingredients during subsequent years. The calcium salt was approved for use in baking by the Food and Drug Administration in 1961 and the sodium salt in 1967. The sodium salt has been marketed under the trade name of Emplex. As early as 1961 improved baking performance was recorded when calcium stearoyl-2-lactylate was used in the formula for the production of whole-wheat, rye, and raisin breads (21). Thus, the beneficial influence of those emulsifiers in baking, when using other than wheat flour, has been recognized for some time.

Research work, encouraged and supported since 1962 by the Food and Agriculture Organization of the United Nations at the Institute for Cereals, Flour and Bread-TNO, Wageningen, the Netherlands, led to studies on bread made from non-wheat flours (8,9,10). Kim and de Ruiter, in March 1969, at the meeting in Rio de Janeiro, Brazil, in the Center for the Application of Science and Technology for the Development of Latin America, reported the beneficial results of using calcium stearoyl-2-lactylate in the baking formula when producing non-wheat bread, and their research was subsequently reported elsewhere (9, 12).

Present Research. Pomeranz, Shogren and Finney (14,15) have for many years pursued research on wheat flour lipids and have studied extensively the properties of glycolipids in baking. They discovered that small amounts of glycolipids improved breadmaking properties when soy flour or other protein supplements were used in amounts as high as 16%. In the course of these experiments the effectiveness of glycolipids was compared with the baking results obtained from the use of many other surfactants, including sodium stearoyl-2-lactylate. This additive was found to perform satisfactorily when protein concentrates were added to dough. Sodium stearoyl-2-lactylate is, indeed, effective as an improver; but so, too, are a number of other compounds, some of which are considerably more effective in carrying protein supplements and have greater stability (5).

Although sodium stearoyl-2-lactylate had been used for years as a dough improver by the baking industry and its usefulness as a surfactant for high-protein bread production established by prior published research; nevertheless, publicity was later associated with its use and termed a scientific "break-through" (6,23). Originality and prior research and knowledge in this field were recognized by the issuance of a public patent in 1972 to Pomeranz and Finney (18) covering the production of high-protein bread.

Calcium and sodium stearyl lactylates are approved by the Food and Drug Administration. Until recently, there has been no need for the commercial production of FDA-approved synthetic glycolipids and related natural compounds for use in baking because of lack of commercial interest in high-protein bread production. This situation appears to be changing and there is now some interest in developing high-protein bread, and there are government subsidized programs for both domestic and foreign marketing of nutritionally enriched bread. The U.S. Patent Office has recently approved a public patent to Pomeranz and Wehrli on the synthesis of glycosyl glycerides of the types that are present in wheat flour (25). Those glycolipids are superior in their performance to any of the synthetic surface active agents on the U.S. market. Unfortunately, the yields of glycolipids manufactured by the patented procedure are too low for commercial production. However, Japanese sucrose palmitate and certain other sucroesters from a second Japanese manufacturer (with U.S. interests) are at least fully equal to the naturally occurring glycolipids of wheat flour.

As mentioned previously, probably a reasonable definition of high-protein bread, on a worldwide basis, would be bread with a protein content of approximately 15% on an as-is basis (22% on a moisture-free basis) compared to normal bread which would have approximately 9% protein (on an as-is basis). The high level of protein supplementation necessary to produce high-protein bread, according to the above definition, would require a potent additive to make the supplemental proteins compatible with the wheat flour proteins. The use of additives in baking brings about other considerations including objections and legal restraints.

The need for enriched flour (wheat) in breadmaking by adding proteins or amino acids is not nearly so clearly established as the need to enrich white flour with minerals and vitamins (17). When the production of high-protein bread requires an additive for satisfactory baking operation, both technical and economic considerations become evident. There has been a tendency throughout much of Europe and other areas of the world to produce natural or additive-free bread (20). The stigma against additives in bread is being overcome slowly, largely because of the need to use additives to reduce bread staling. Undoubtedly , in the course of time, objections to using additives to improve the nutritive value of processed foods will lessen and eventually disappear. Of course, no additive hazardous to public safety and health can be considered for use (2).

The production and sale of high-protein bread in substantial amounts has some serious difficulties to overcome. There is no unanimity of opinion that there is a need for protein supplementation in the human diet to the extent often claimed. Nor is there agreement that high-protein bread is the logical way to improve nutrition. Protein sources useful in bread production are limited, expensive, and often lack uniformity and availability. The addition of a special additive at high levels of protein supplementation increases cost to the consumer and can be in conflict with laws limiting the use of additives.

Conclusions. The overall increasing use of proteins in foods such as dairy products, pet foods, and processed meats (11) has tended to increase the cost of protein supplements to the baking industry and has lessened the need for protein-fortified baked goods. Textured and spun types of protein products are finding wide use in the food industry and many new developments are on the way. These events have to some extent deemphasized high-protein-bread developments,but the baking industry likely will find various new ways to use protein supplements. Competition within the food industry in marketing protein-enriched and modified foods will be intense and baked goods will be but one of many avenues available to the public to improve the nutritive value of the diet.

Literature Cited

1. Abbott, J. C. The efficient use of world protein supplies. PAG Bulletin 3: 25-35, 1973. United Nations, N. Y. 10017.
2. Angeline, J., and Leonardos, G. Food additives. Food Tech. 27: 40-50, 1973.
3. Bechtel, W. G., Hammer, G. E., and Ponte, Jr., J. G. Effect of calcium stearyl-2-lactylate in bread made with nonfat milk solids of varying baking quality. Cereal Chem. 33: 206-212, 1956.
4. Finney, K. F. Loaf volume potentialities, buffering capacity, and other baking properties of soy flour in blends with spring wheat flour. Cereal Chem. 23: 96-104, 1946.
5. Finney, K., and Shogren, M. Surfactants supplement each other, make foreign proteins compatible in breadmaking. Baker's Dig. 45(1): 40-41, 1971.
6. Hoover, W. J., and Tsen, C. C. Add to high protein baked products. Southwestern Miller. October 13, 1970.
7. Johnson, P. E. High-protein foods for peace. Cereal Science Today 18: 138-141, 1973.
8. Kim, J. C., and de Ruiter, D. Bread from non-wheat flours. Food Technol. 22: 867-878, 1968.
9. Kim, J. C., and de Ruiter, D. Bread from non-wheat flours. Protein-enriched Cereal Foods for World Needs, Ed. by Max Milner, American Association of Cereal Chemists, St. Paul, Minn. 1969.
10. Kim, J. C., and de Ruiter, D. Bakery products with non-wheat flours. Baker's Dig. 43(3): 58-63, 1969.
11. Lockmiller, N. R. Increased utilization of protein in foods. Cereal Sci. Today 18: 77-81, 1973.
12. Marnett, L. F., Tenney, R. J., and Barry, V. D. Methods of producing soy-fortified breads. Cereal Sci. Today 18: 38-50, 1973.
13. Pomeranz, Y. Soy flour in breadmaking. Baker's Dig. 40(3) 44-48, 78, 1966.
14. Pomeranz, Y., Shogren, M., and Finney, K. Improving breadmaking properties with glycolipids. I. Improving soy products with sucroesters. Cereal Chem. 46: 503-511, 1969.
15. Pomeranz, Y., Shogren, M., and Finney, K. Improving breadmaking properties with glycolipids. II. Improving various protein-enriched products. Cereal Chem. 46: 512-518, 1969.
16. Pomeranz, Y. Protein-enriched bread. CRC Critical Reviews in Food Technology 1: 453-476, 1970.
17. Pomeranz, Y., and Shellenberger, J. Bread Science and Technology. The Avi Publishing Company, Inc., Westport, Conn. 1971.
18. Pomeranz, Y., and Finney, K. F. Protein-enriched baked products and method of making same. U. S. Patent Office, No. 3,679,433, July 25, 1972.
19. Protein Advisory Group of the United Nations. Spring 1973, Vol. III, No. 1, United Nations, New York 10017.
20. Shellenberger, J. A. The history and future of additives and residues in foods. International Assn. Cereal Chemistry, Trans. 1964. Vienna, Austria.
21. Tenney, R., and Schmidt, D. Sodium stearyl-2-lactylate, its functions in yeast leavened bakery products. Baker's Dig. 42(6): 38-42, 1968.
22. Thompson, J. B., and Buddemeyer, B. D. Improvement of flour mixing characterisitcs by a stearyl lactylic acid salt. Cereal Chem. 31: 296-302, 1954.
23. Tsen, C. C., Hoover, W. J., and Phillips, D. High-protein breads. Baker's Dig. 45(2): 20-23, 26, 74, 1971.
24. Tsen, C. C., and Hoover, W. J. High-protein bread from wheat flour fortified with full-fat soy flour. Cereal Chem. 50: 7-16, 1973.
25. Wehrli, H. P., and Pomeranz, Y. Synthesis of galactosyl glycerides and related lipids. Chem. Phys. Lipids 3: 357-370, 1969.

HIGH-PROTEIN BREAD FLOUR BLENDS FOR GOVERNMENT PURCHASE

M. M. Bean, D. K. Mecham, M. M. Hanamoto
and D. A. Fellers
Western Regional Research Center, Agricultural Research Service,
United States Department of Agriculture

That there is hunger and malnutrition in the world has always been recognized. Many nations have contributed vast resources to aid the less fortunate, either directly or through international organizations such as the U.N. While it would be most desirable to provide everyone with the quantity, quality and variety of food we have here in the United States, several factors dictate against this. These include transportation, supply, cost, personal preferences, and cultural and religious beliefs of the recipients. Out of necessity we must turn to the most abundant, inexpensive, acceptable and easily transportable foods; chiefly the grains and oilseeds. Of this group, wheat is most important for feeding people. Its place could be easily documented with figures, showing the vast amounts consumed annually throughout the world. It can also be illustrated with the universal propaganda tool used by every nation, their postage stamps. Figure 1 shows postage stamps of several nations and a U.N. cover (envelope), issued to commemorate the United Nations Food for Peace-Freedom from Hungar Campaign of 1963.

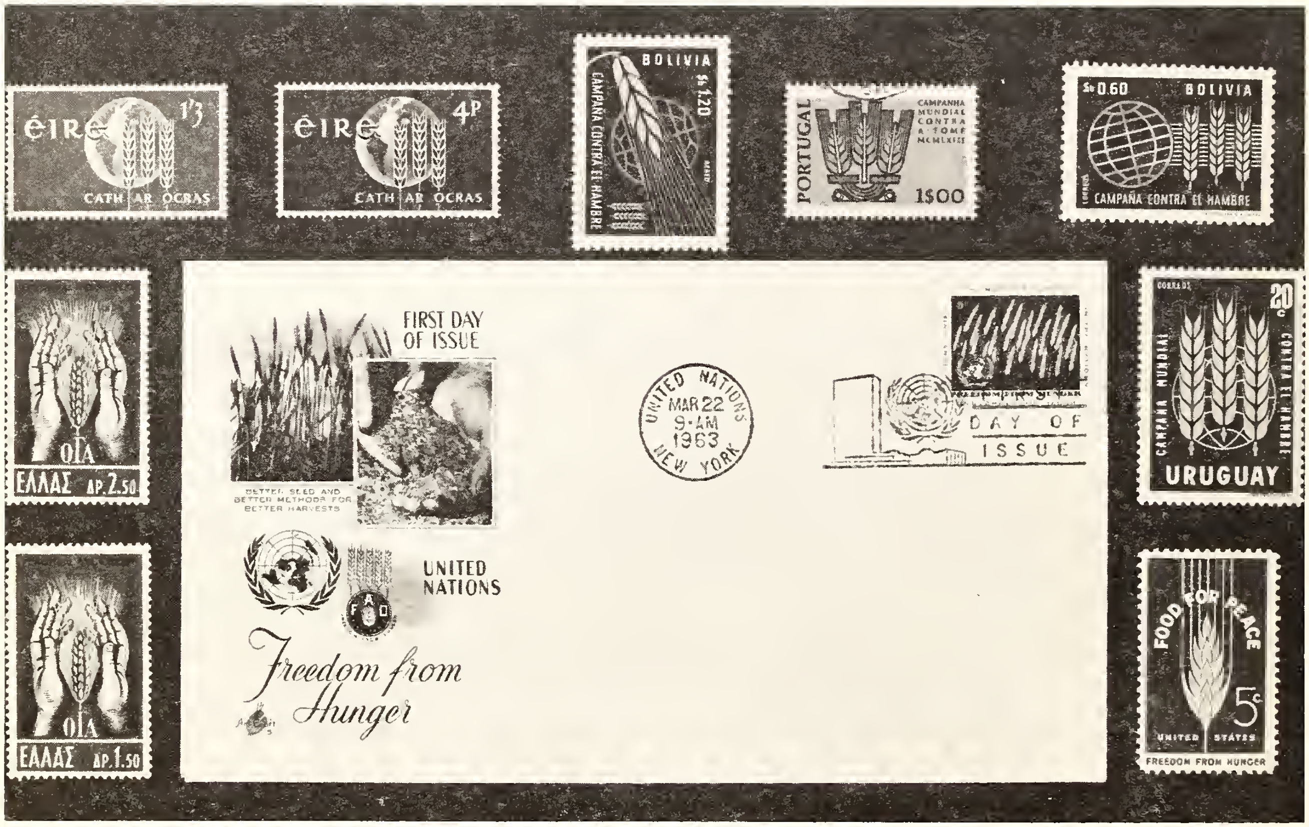


Figure 1. Postage stamps commemorating the U.N. Freedom from Hunger program depict a central role for wheat.

U.S. Food for Peace Program. This program operates under Public Law 480, Title II. The actual operations are supervised by the Office of Food for Peace in the Agency for International Development (AID). The commodities included are those recommended by the Department of Agriculture and purchased by the Agricultural Stabilization and Conservation Service (ASCS) in the Department of Agriculture.

When Public Law 480 was first enacted in 1954, its main thrust was to share our abundant and surplus agricultural products with less fortunate nations as a means of helping them develop their economics. The Food for Peace Act of 1966 substantially amended PL 480 to include products that were not in surplus and to enrich and fortify Title II commodities thus allowing for nutritional improvement. Since that time, several nutritionally-engineered products have appeared in the program. Most important in terms of quantities purchased have been soy-fortified bulgur; WSB, wheat-soy blend; and CSM, a corn-soy-milk blend. These last two high-protein products are easily reconstituted into gruels or milk for feeding infants, children and pregnant or nursing mothers.

Protein-Fortified Bread Flours. More recently, three high-protein blends described in Table 1 have been developed specifically for use in yeast-leavened breads. The first of these is Flour Blend A, an all-wheat blend containing 70 parts of straight grade bread flour and 30 parts of wheat protein concentrate (WPC). The other two high-protein blends are both soy-fortified and contain 6 or 12% soy flour added to bread flour on a replacement basis. A range of potassium bromate is specified to ensure an optimum amount which is decided by the contracting mill. The soy-fortified blends also contain a dough conditioner, sodium stearoyl-2-lactylate (SSL), to counteract the gluten-diluting effects of the soy flour. All three blends are supplemented with the nutrients used in this country (thiamine, riboflavin, niacin and iron) and also with vitamin A and calcium, both of which have been found to be deficient in the diets of the people of the recipient countries.

Table 1. High-protein bread flour blends. Enrichment includes thiamine riboflavin, niacin, iron, Vitamin A and calcium.

	Blend A	6% SFF	12% SFF
Bread Flour, parts	70	94	88
High-Protein Flour, parts	30	6	12
Potassium Bromate, ppm	40-60	10-40	10-40
SSL, parts	---	0.28	0.5

Flour Blend A. This all-wheat blend (Table 1) (1), was developed in the late 60's after it was determined there was a need for a bread-type product as an alternative to the WSB and CSM. The wheat protein concentrate, obtained from re-milling millfeeds, has a low fiber content and 23% protein with a considerably higher lysine content than found in white flour. When 30 parts of WPC is added to 70 parts bread flour, the protein content of the resulting blend is increased from 11% to 13.7% and the Protein Efficiency Ratio (PER) is increased due to the extra lysine contributed by the WPC. The first Blend A was designed for use in flat breads. Development work was carried out in India, Pakistan, and Egypt on the chapatties and on yeast-leavened, Arabic-type flat breads. The first shipments sent to India and Ceylon were used not only in chapatties but also in pan bread which was, at that time, becoming popular in these areas. Bitter off-flavors developed in some of the Blend A and bread making ability was impaired. The functional defects were more apparent in pan bread than in flat bread. These problems were found to be related to storage in hot, humid areas. Follow-up research at Western Regional Research Center (WRRC) determined that product stability could be maintained if the moisture content of the blend was reduced to 10.5% from the previous maximum of 13% and packed in multi-walled paper bags. These bags have a plastic liner to insure retention of the low moisture. A bread baking test was added to the specifications to insure retention of functional properties after drying the blend or components to the lower moisture content. Two purchases have been made under the new specifications (2). In both cases the loaf volumes were 2600-2800 cc, well over the 2150 cc load volume required in the specifications.

Soy-Fortified Bread Flours. In 1971, Dr. William Hoover of Kansas State University reviewed (3) the wheat-based products used in foreign assistance programs under PL 480. Up to that time Blend A was the only commodity shipped that was intended for bread use. Dr. Hoover described what he termed a new "second generation" composite flour product developed at Kansas State and referred to at that time as Blend K. Several publications from Dr. Hoover's group have elucidated the baking characteristics of Blend K (4,5,6). Using their work as a background along with studies by several other people working on high protein blends (7-11) and with the help of Northern Regional Research Laboratory personnel, the Cereals group, at WRRC, developed specifications for government-purchase of the two soy-fortified flour blends (12). The first purchases were made in October 1972. Table 2 shows the amounts of 6 and 12% blends purchased through June, 1973, when purchases were temporarily curtailed because of scarcity of wheat. The cost and major destinations are also included.

The Philippines have received more than half of the total soy blends shipped. Most of the soy-fortified flour has been used for child feeding in school-lunch programs. In the Philippines it has been used primarily in a product called Nutribun to be described later.

Table 3 shows some of the quality requirements described in the ASCS specifications for the wheat and soy flour components and for the finished 6 and 12% soy-fortified flour blends. Heavier toasting of the soy flour ingredient would give a lower Nitrogen Solubility Index (NSI) and a darker color which might be objectionable in the blend. If a higher NSI were specified the toasting might be too light to inactivate trypsin inhibitors and other factors which interfere with utilization of the protein.

Table 2. Soy-fortified flours (SFF)

	6% SFF	12% SFF	Export Donation Flour
Quantity purchased 10/72 through 6/73, lbs.	15,600,000	36,450,000	∿550,000,000
Cost range, 10/72 to 6/73, $/cwt.	8.45-10.65	8.59-12.78	7.61-8.83
Major recipient countries	Philippines India Equador Bolivia Chile Colombia	Philippines India Colombia	many

Table 3. Partial requirements for soy-fortified flours and some of the ingredients

	Wheat Flour	Defatted Soy Flour	6% SFF	12% SFF
Protein, % [1/] minimum	11	52	14.0	16.2
Moisture, % maximum	13	8	12.7	12.4
NSI, range	--	55-75		
Loaf Volume, cc. minimum	--	--	2550	2550

[1/] N X 5.7 for wheat flour; N X 6.25 for soy and blends.

The minimum loaf volume is the same for both blends and is based on a straight dough formula without shortening and using 525 g dough. The baking test was designed to reflect the overall quality of the blends and the omission of shortening makes the test more sensitive to the effects of the dough conditioner, SSL. There is, as yet, no quick and easy method for testing the amount of SSL in the blend. The method available takes longer than a baking test.

Figure 2 demonstrates the effects of shortening in the bread formula as outlined in the specifications (12). The first three loaves contain no shortening and no dough conditioner. The first loaf is

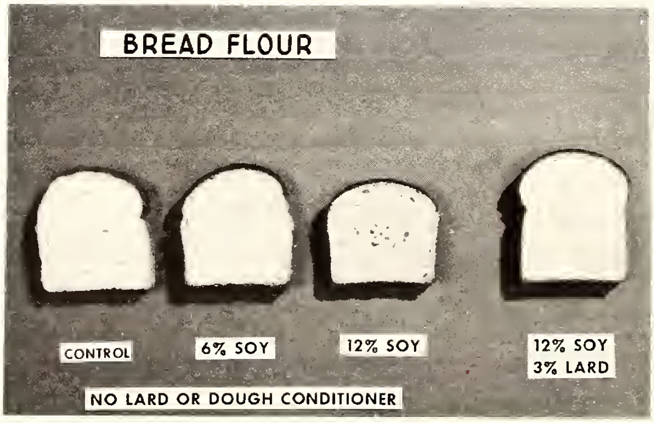


Figure 2. Loaf volume depressant effect of soy flour and the ability of lard to reverse the effect.

made with bread flour only. The depressing effects of the addition of 12% soy flour are shown in loaf 3. The last loaf shows the improvement in appearance and loaf volume which are quite marked with 3% lard. The SSL levels specified in the blends produce the same effect as the fat. Because fat is often unavailable to recipients who use the donated flours, it was deemed necessary to supply a high-protein flour that would yield bread at least as acceptable as that from the white flour they have been receiving. The SSL offered a convenient fat substitute because of its functional properties and the ease of dry mixing it into the blends as they are produced at the mill.

The nutritional rationale for the inclusion of soy flour in a wheat flour blend is based on the complementary effects of the amino acid array in the wheat and soy flours. The soy flour supplies not only more protein but also extra lysine which is deficient in the wheat flour. Figure 3 shows how the increased protein content has a higher nutritional quality in terms of PER than the wheat flour alone.

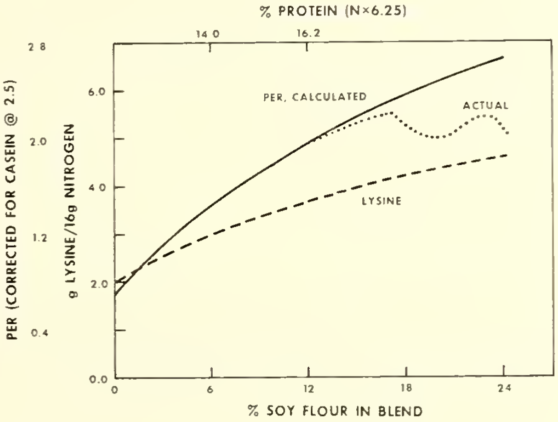


Figure 3. Addition of defatted soy flour to wheat flour increases lysine and protein content and improves Protein Efficiency Ratio.

The lower curve represents the increase in lysine in the blend with increasing levels of soy flour up to 24% on a replacement basis. The other curve plots the PER which is a standard measure of protein quality based on rat feeding studies. It was calculated from published data (13) based on the increase in PER per gram of lysine added to wheat flour, and assuming adequate quantities of other amino acids. Significant increases in PER result from the addition of 6 and 12% soy. When more than 12% soy is added, the calculated PER continues to increase. In actual use, the PER of wheat-soy blends tend to level out between 2.0 and 2.2 due to other limiting effects. At the top of this graph the values are shown for the resulting protein content (N X 6.25) of the 6 and 12% soy-fortified blends. Bread made from these blends has a protein content (dry basis) close to the values for the blends, unless other proteinaceous ingredients are included in the formula.

In many countries, there is a legal minimum protein content of 22% specified for high-protein breads. To achieve this, the dry ingredients in the formula would have to contribute 22% protein, considerably more than these blends. Countries having these standards depend to a large extent on wheat gluten to achieve the high protein content and still maintain bread making ability. The protein in wheat gluten would have a lysine content similar to or below that of bread flour. Therefore, no matter how much was added, the PER would remain low unless a lysine source were included. Such standards for high protein bread have been used in countries such as England and the Republic of Ireland where adequate quantities of animal protein are present in the diet. By contrast, the needy people in the underdeveloped countries have very limited animal protein. For them, it seems equally important to increase the biological value of the protein along with its content assuming sufficient calories are also supplied. Increasing one without the other has limited value for malnourished people.

It was noted earlier that most of the soy-fortified blends had gone to the Philippines and to India where considerable amounts are used in buns and bread distributed in school-lunch programs. Reports received from Food for Peace, Western Wheat Associates, Kansas State University and C. J. Patterson have all confirmed the acceptability of the soy-fortified flours in the nutribun formulation. Table 4 shows two typical formulas for bread products, one used in the Philippines and the other in India. In both countries, a nutritional product that was easily distributed was the main objective. In the Philippines, the nutribun was developed for the Philippine School Nutrition Program which is a joint project

Table 4. Formula and nutritional criteria for nutribuns in the Philippines and India.

Formula	Philippines %	India %
12% Soy-Fortified Flour	100	100
Sugar	12	8
Vegetable Oil	5	8
Yeast	2 (dry)	3 (compressed)
Salt	1.5	1.5
Water	Variable	Variable
Nutritional Criteria	17 g protein and 500 calories per bun (about 170 g bun at 32% H_2O)	10 g protein and 300 calories per 100 g bun at 32% H_2O

of the Philippine government, the U.S. AID and American voluntary agencies such as CARE, Catholic Relief Services, Church World Services and the Seventh-Day Adventist Welfare Service. The program recognized that 34% of the school age children were eating substantially fewer calories and less protein than recommended for maintaining good health. This shortage was made up by providing a bun having 500 calories and 17 to 18 g protein. Originally milk solids were used along with wheat flour. The 12% soy-fortified flour provided a timely replacement when the milk solids became expensive and in short supply.

In India the composition is slightly different with less sugar and increased oil (8%) to provide a greater caloric density. Their nutritional requirements include 10 g of protein and 300 calories per 100 g bun at 32% moisture. Presently more pan bread than buns is made from the same formulation in India for child and adult feeding programs. The vegetable oil is generally soy oil which is also donated through the U.S. relief program. The amount, which seems high by our standards, provides an increased palatability besides adding much needed calories.

Figure 4 shows the volume improvement resulting from the use of high oil levels in the specification bakery formula. These loaves were baked without a dough conditioner. In the 12% soy-fortified flour blend, 3% soy oil produced only a slight volume increase but 8% oil gave a bread with a loaf volume that would pass specifications as well as contribute to the eating quality of the bread.

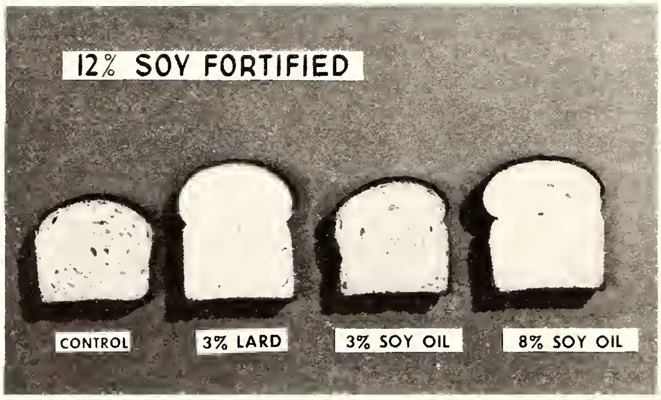


Figure 4. Eight percent soy oil in scy-fortified bread formulation has improving effect similar to 3% lard.

Technical problems in producing breads in India have been related to the high oil content and specifically to the time at which it is added. Dough mixing is commonly done in an elbow-type mixer (Artofex-type) similar to pie dough mixers used in this country. Dough development is slow, often taking 20 to 30 minutes compared with 5 to 10 minutes in U.S. conventional bread dough mixers. If the oil was added at the beginning of mixing, it coated the flour particles and reduced water absorption considerably, resulting in a lower bread yield. If the oil was added after dough development, such high levels were not easily incorporated and the resulting dough tended to disintegrate and become very sticky, creating problems during sheeting and moulding. The Wheat Associates' technical representative in India worked with the bakers and found it was best to add the oil after the flour was wet and beginning to pick up but before gluten development. The time span for addition is relatively long with these slow mixers.

In South American countries more of the 6% soy-fortified blend has been used and often in conjunction with WSB to increase the protein content. The voluntary agencies are considering requesting the 12% blend because of the convenience of having one product instead of two supplying the protein source. Reports received indicate the blends have been used in programs similar to those in India and the Philippines. Buns are distributed at school and also via health care programs to pre-school children.

In all the countries, acceptance of products made with the soy-fortified flours has been extremely positive, and this acceptance is reflected by the following interesting comments.

1. School attendance has increased.

2. Parents are sending extra money to school for the purchase of buns for the family.

3. No stale returns because families purchase the leftovers.

Thus far, no problems have been reported that would suggest functional deterioration of the soy-fortified flours during transit to or storage in the recipient countries. Laboratory experiments at WRRC have suggested some loss of loaf volume potential during more severe storage of 2 to 6 months at 100°F and 13% moisture. Additional testing has suggested other dough conditioners are more stable than sodium stearoyl-2-lactylate. Further studies are underway, designed to assess the relative stability of various dough conditioners, with emphasis on those that are fine powders, easily blended in at the flour mill. Such studies should supply valuable information for further improvement of high protein blends.

Finally, the use of high-protein blends does not need to be limited to the government's donation program. During their development, a great deal of information has been accumulated by WRRC, by Dr. Hoover's group at Kansas State University, by the flour millers supplying the blends, and by the manufacturers of the dough conditioners. It seems reasonable that some of this technology might be more extensively applied here in the United States. These highly nutritious products seem well suited for the domestic market where the consumer is looking for new, less expensive protein sources.

Literature Cited

1. Fellers, D. A., and Bean, M. M. Baker's Digest 44(6): 40 (1970).

2. U.S. Department of Agriculture. Agricultural Stabilization and Conservation Service Announcement WF-3 Revised for the purchase of Wheat Flour Blend A, January 12, 1971 (ASCS Commodity Office, 6400 France Avenue South, Minneapolis, Minnesota 55435).

3. Hoover, W. J. Proceedings of the 7th National Conference on Wheat Utilization Research. ARS-NC-1. Manhattan, Kansas (1971).

4. Tsen, C. C., Hoover, W. J., and Phillips, D. Baker's Digest 45(2): 20 (1971).

5. Tsen, C. C., and Hoover, W. J. Baker's Digest 45(3): 38 (1971).

6. Tsen, C. C., and Tang, R. T. Baker's Digest 45(5): 26 (1971).

7. Finney, K. F., Rubenthaler, G., and Pomeranz, Y. Cereal Science Today 8: 166 (1963).

8. Pomeranz, Y., Shogren, M. D., and Finney, K. F. Cereal Chem. 46: 503 (1969).

9. Finney, K. F., and Shogren, M. D. Baker's Digest 45(1): 40 (1971).

10. Ehle, S. R., and Jansen, G. R. Food Technol. 19: 1435 (1965).

11. Mizrahi, S., Zimmermann, G., Berk, Z., and Cogan, U. Cereal Chem. 44: 193 (1967).

12. U.S. Department of Agriculture. Agricultural Stabilization and Conservation Service Announcement WF-9, Purchase of soy-fortified bread flour for use in export programs, September 27, 1972 (ASCS Commodity Office, 6400 France Avenue South, Minneapolis, Minnesota 55435).

13. Howe, E. E., Jansen, G. R., and Gilfillan, E. W. Am. Journal of Clinical Nutrition 16: 315 (1965).

INERT ATMOSPHERES: A SUBSTITUTE FOR CONVENTIONAL CHEMICAL FUMIGATION

C. L. Storey
Grain Marketing Research Center, Agricultural Research Service,
United States Department of Agriculture

Hazards inherent in the handling and application of grain fumigants and chemical reactions resulting in residues within the fumigated commodity are problems associated with many of the grain fumigants in common use today. These problems would be significantly reduced by the substitution of nonchemical control methods such as the use of inert atmospheres for the control of insects in bulk stored grain. Various combinations of atmospheric gases have been tested, all involving restriction of O_2 available to the insect. Several techniques have been used in laboratory studies to manipulate the O_2 concentrations available to stored grain insects. Baily (1-4) conducted tests with a gas-mixing apparatus designed to produce various mixtures of N_2, O_2, and CO_2 which were passed over test insects in a continuous flow. Harein and Press (5) used premixed binary and ternary mixtures of N_2, O_2, and CO_2 released from pressurized cylinders and passed through glass jars containing cages of test insects. Similar tests were conducted by Lindgren and Vincent (7) and AliNiazee (6) with static conditions (no air movement). Nitrogen containing 0.5 and 1% O_2 was used to purge 1-lb. containers of sorghum in tests by Person and Sorenson (8). Reports of tests in commercial storage facilities are more limited. A mixture of methylformate and CO_2 was applied to 6,000 bu. bins of wheat in 1935 by researchers in Cereal and Forage Insect Investigations of the Bureau of Entomology and Plant Quarantine, USDA (unpublished data). The gas was released from pressurized cylinders and passed through a copper coil immersed in hot water. The vaporized gas was released into the grain mass through a pipe which was pushed below the surface. A unique system was developed by Jay et al. (9) for applying a large volume of CO_2 in peanut silos. In this system a mobile liquid CO_2 storage tank was equipped with electrically operated vaporizers for rapid conversion of the liquid CO_2 to a gas. The CO_2 was released into the overhead space above the peanuts and recirculated through the silo. Similar tests were conducted by Storey (unpublished data) in which the CO_2 was released into aeration ducts in the bottom of 15,000 and 30,000 bu. tanks of wheat and passed upward through the grain mass. Results obtained in these various studies were inconclusive; however, some general observations can be made. Most stored-grain insects are affected by atmospheres containing less than 3% O_2 or more than 40% CO_2. The lethal effect of atmospheres producing mortality is increased by increased treatment temperatures, decreased humidity, or extended exposure periods. Atmospheres of N_2 require much lower O_2 concentrations to be effective than are required in atmospheres of CO_2. Immature stages of stored-product insects are more tolerant of O_2-deficient atmospheres than are the adult stages.

Three factors are essential to the use of inert atmospheres for control of insects in stored grain; 1) the atmosphere must be easily obtained in sufficient volume to displace existing atmospheres in large bulk storage; 2) the atmosphere must be lethal to storage pests within a reasonable time; and 3) the atmosphere must have no harmful effect on the quality of the treated commodity.

The inert atmosphere used by the feed industry for the preservation of vitamin content, color, weight, and palatability of alfalfa pellets (10) appears to meet these requirements. This atmosphere is nearly devoid of O_2 and is produced by gas-fired exothermic inert-atmosphere generators. The capacities of these generators often range from 50,000 to 100,000 cu. ft./hr. of inert gas. During operation air and fuel are ignited under controlled ratio and pressure regulation. Combustion takes place in a water cooled chamber. The exit gas is further cooled by an indirect heat exchanger or direct contact water cooler. Water droplets are removed by passing the gas through a centrifugal separator. The conversion ratio of fuel to inert atmosphere is about 1 to 10. Composition of the inert atmosphere is less than 1% O_2, 8.5-11.5% CO_2 with the balance principally N_2. This combustion product gas has been registered (11) as a food additive permitted in food for human consumption and is being used in the meat packaging industry.

The use of these generators for displacing normal atmospheres was investigated in a series of tests (12) conducted in 130-ft. high concrete elevator tanks containing about 20,000 bu. of wheat. The generators used in the tests are part of a large alfalfa pellet storage operation which encompasses a major portion of an entire elevator complex. There are two generators in this system each capable of generating 15,000 cu. ft. of inert atmosphere per hour. The units are located in a small building adjacent to the elevator and interconnect with a large supply duct located beneath the storage tanks. Feeder lines extend from the main supply duct up through the base of each tank.

During operation, full flow is maintained upward through the alfalfa pellets in each tank until a zero oxygen reading is obtained at the top of the tank; thereafter, only sufficient flow to prevent oxygen from rediffusing into the tank is released.

In our tests we substituted wheat for the pellets and measured displacement of the normal atmosphere within the grain mass from tiers of sample lines with sample points and test insects spaced at 20-ft. intervals throughout the 130-ft. depth of the elevator tank.

An O_2-deficient atmosphere was obtained throughout the grain mass in each test and was successfully maintained during the balance of 72-and 96-hr. exposure periods. An example of the oxygen distribution pattern obtained during displacement of the existing atmosphere in the tanks is given in Table 1.

Table 1. Average O_2 concentrations and test insect mortality obtained at center and wall locations in a 20,000-bu tank of wheat. Inert atmosphere[1] produced by an exothermic inert-atmosphere generator and introduced through the floor by using a 1-1/2 in. pipe. Tank purged overnight prior to treatment.

	% oxygen concentrations						%, mortality, 96 hr.	
Location (Depth)	Before filling	After filling	After indicated hours 4	8	24	96	Adult confused flour beetle	Immature rice weevil
10 ft	4.3	18.3	11.7	2.5	0.9	7.5[2]	88	59.2
30 ft	4.0	16.3	7.9	0.5	0.3	0.7	100	54.7
50 ft	3.9	12.5	4.1	0.4	0.2	0.5	100	49.0
70 ft	3.9	10.0	1.2	0.4	0.2	0.4	100	43.5
90 ft	3.9	5.8	0.3	0.3	0.2	0.2	100	47.0
110 ft	3.9	0.9	0.2	0.2	0.2	0.2	100	67.6
130 ft	2.4	0.1	0.1	0.1	0.1	0.1	100	70.4

[1] Composition of the inert atmosphere $<0.1\%$ O_2, 8.5-11.5% CO_2, and the balance principally N_2.

[2] Strong shifting winds prior to taking of this sample resulted in some diffusion of outside air into the top of the tank.

The time required to displace the existing atmosphere with an O_2-deficient atmosphere was dependent upon the rate of flow of gases released into the tank and the degree of pretreatment purging achieved prior to loading the tank with grain. In tests without the pretreatment purging, the O_2 deficient zone moved upward through the grain mass at the rate of about 8 ft/hr. Nearly complete displacement was obtained throughout the grain mass after 16 hours. Overnight pretreatment purging of a tank prior to loading, reduced O_2 concentrations to less than 5% throughout the tank. Filling the tank with wheat left a stratification of O_2 concentrations ranging from less than 1% at the bottom of the tank to near normal concentrations at the top. After 4 hours of treatment, the O_2 was displaced in the bottom two-thirds of the tank and after 8 hours all but the overhead space contained less than 1% O_2.

Control of the test insects exposed to the O_2-deficient atmosphere was only partially successful. Oxygen concentrations of less than 1% for 24 hr killed the adult confused flour beetles, but were not effective against the immature stages of the rice weevil for time periods of 72 to 96 hr. Subsequent tests in which exposure periods were extended up to 4 weeks indicate the order of tolerance of rice weevils to low O_2 concentrations is: pupae, most tolerant; eggs; larvae; adults, least tolerant. No life stages however have survived exposures of 2 weeks or longer.

During our field tests with the inert atmosphere generators, studies were conducted to determine the effect of the low oxygen atmosphere on grain quality. Factors investigated included germination, grade, and baking and milling studies. Results obtained in the studies did not show a significant difference between untreated controls and the corresponding treated wheat in any of the factors measured.

The cost of consumables (natural gas, electricity, and water for cooling) for operation of each 15,000 CFH generator is about $1.70 per hour. Treatment costs with these generators will depend on how effectively the total amount of inert atmosphere generated each hour can be used. For example, 15,000 CFH would treat about 20 tanks of wheat (400,000 bu.) for 14 days at a cost of about $500.00. The same amount of wheat fumigated at an average cost of 1/2¢ per bu. would cost $2,000.00. If less grain was treated, the cost of chemical fumigation would decline proportionately. The cost of inert atmosphere treatment, however, would remain nearly the same because the output of these machines cannot be turned down more than 20 to 30% of their rated output. The generators are also expensive ranging from $3,350.00 for a 500 CFH unit to about $10,000.00 for a 15,000 CFH unit.

We are currently involved in the development of a low-capacity generator specifically designed for use in pilot scale operations at the Grain Marketing Research Center. This laboratory unit will provide the flexibility needed to conduct repetitive tests under controlled conditions and the long treatment periods necessary to determine the effects of the gas on grain quality. From this research we will develop practical guidelines for the installation and operation of these generators in commercial storage facilities.

Literature Cited

1. Bailey, S. W. Air-tight storage of grain; its effect on insect pests. I. Calandra granaria L. (Coleoptera,Curculionidae). Aust. J. Agric. Res. 6(1): 33-51, 1955.

2. Bailey, S. W. Air-tight storage of grain; its effect on insect pests. II. Calandra oryzae (small strain). Aust. J. Agric. Res. 7(1): 7-19, 1956.

3. Bailey, S. W. Air-tight storage of grain; its effect on insect pests. III. Calandra oryzae (large strain). Aust. J. Agric. Res. 8(6): 595-603, 1957.

4. Bailey, S. W. Air-tight storage of grain; its effect on insect pests. IV. Rhyzopertha dominica (F.) and some other Coleoptera that infest stored grain. J. Stored Prod. Res. 1(1): 25-33, 1965.

5. Harein, P. K., and A. F. Press, Jr. Mortality of stored-peanut insects exposed to mixtures of atmospheric gases at various temperatures. J. Stored Prod. Res. 4(1): 77-82, 1968.

6. AliNiazee, M. Taskeen. Susceptibility of confused and red flour beetles to anoxia produced by by helium and nitrogen at various temperatures. J. Econ. Entomol. 65(1): 60-63, 1972.

7. Lindgren, D. L., and L. E. Vincent. Effect of atmospheric gases alone or in combination on the mortality of granary and rice weevils. J. Econ. Entomol. 63: 1926-8, 1970.

8. Person, N. K., Jr., and J. W. Sorenson, Jr. Use of gaseous nitrogen for controlling stored-product insects in cereal grains. Cereal Chem. 47(6): 679-86, 1970.

9. Jay, E. G., L. Redlinger, and H. Laudani. The application and distribution of carbon dioxide in a peanut (groundnut) silo for insect control. J. Stored Prod. Res. 6(3): 247-54, 1970.

10. Kruger, A. H. Inert atmosphere for the preservation and protection of feeds in storage. Industrial Gas Applications Book, Bull. 181. Pacific Gas and Electric Co., San Francisco, Calif., 1960.

11. Anon. Food additives permitted in food for human comsumption. Federal Register, Part 121-Food Additives, Subpart D, pp 6918-6919, August 2, 1961.

12. Storey, C. R. Exothermic inert-atmosphere generators for control of insects in stored wheat. J. Econ Entomol. 66(2): 511-514, 1973.

COMPOSITION AND FUNCTIONAL PROPERTIES OF MILLED FRACTIONS OF TRITICALE

R. A. Anderson, A. C. Stringfellow, and J. S. Wall
Northern Regional Research Laboratory, Agricultural Research Service,
United States Department of Agriculture

Triticale, a wheatlike cereal grain, created by man by selectively crossing wheat and rye, is becoming increasingly known throughout the hard wheat-growing areas of the United States and Canada. While primarily raised as a feed grain, triticale possesses properties that also make it potentially useful in both food and industrial applications. Certain food aspects of triticale are being studied; e.g., baking characteristics (1-5), noodle manufacture (3,6), and brewing (4). Little has appeared in the literature on possible industrial uses for triticale grain or any of its components. Some preliminary work has been done at the NRRL on millability of triticale (7,8). The present report relates to continued studies on both dry- and wet-milling characteristics of three triticale grains.

Materials. The three triticale samples we have studied to date were supplied by Farm Management Services, Inc., Wichita, Kansas. They include FasGro 204, a spring hexaploid grown in Texas, and FasGro 131 and FasGro 385, both winter hexaploids, grown in Kansas. Analyses of these grains and selected wheat and rye samples are given in Table 1. Triticales 131 and 385 appeared to be harder than 204, and differed slightly in appearance from 204, being less wrinkled.

Table 1. Composition of triticales and other (9) cereal grains (moisture-free basis)

Component	Triticale 204	Triticale 131	Triticale 385	Typical Wheat				Typical Rye
				Durum	Hard Red Spring	Hard Red Winter	Soft Red Winter	
Crude protein (N X 5.7),%	17.1	13.9	13.9	15.0	16.4	14.6	12.3	13.4
Crude fat, %	1.7	1.9	1.5	2.2	2.1	1.8	1.8	1.8
Crude fiber, %	3.1	2.4	2.4	2.5	2.7	3.0	2.5	2.6
Ash, %	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.1
Nitrogen-free extract, %	76.0	79.8	80.2	78.3	76.8	78.6	81.4	80.1

Analytical Methods. Chemical analyses were made according to procedures described in Approved Methods of the American Association of Cereal Chemists (10).

Dry Milling and Air Classification. The triticales were milled in a Buhler pneumatic laboratory mill, type MLV-202, to determine their milling characteristics and to obtain flour for wet milling and air classification. Typical milling results are given in Table 2.

Table 2. Milling triticale grain in a Buhler mill (14% moisture basis)

Fraction	Yield, %			Protein, %			Ash, %		
	204	131	385	204	131	385	204	131	385
Straight flour	63.8	61.9	65.0	12.1	10.2	10.4	0.54	0.58	0.58
Shorts	9.9	12.4	13.5	16.5	---	---	2.78	---	---
Bran	26.3	25.7	21.5	---	---	---	---	---	---

Milling presented no problems; there was a clean separation of bran and shorts from the flour. The yield of flour from triticale was lower than usually obtained from hard wheats. Ash contents of the straight flour from the triticales were about the same magnitude as those generally found from hard wheats milled on the Buhler.

To facilitate air classification, flour particles first must be ground finely, a step which is accomplished by passing the flours three times through a pin mill. The basic principle of air classification is diagrammed in Figure 1. The flour particles are impinged on a rotating plate. A stream of

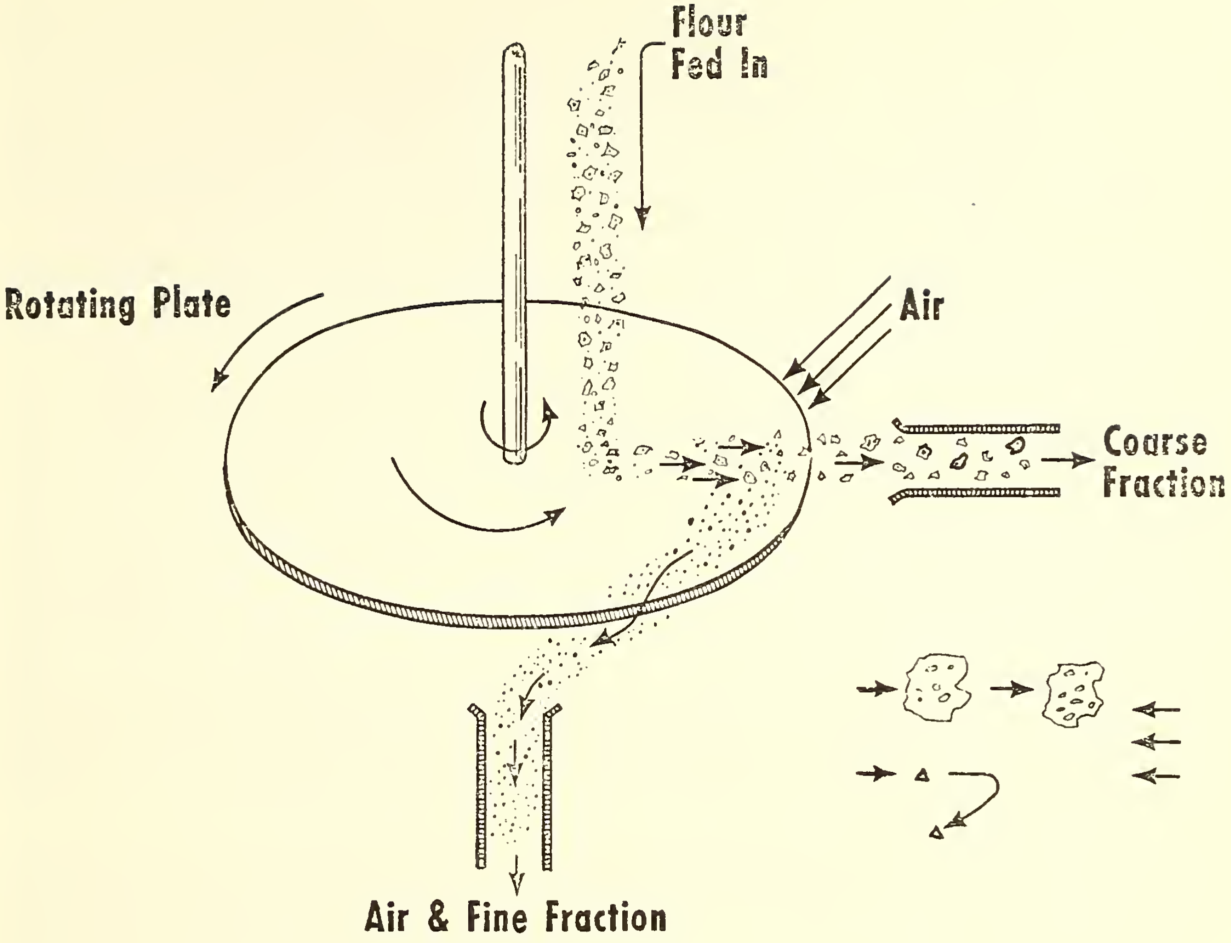


Figure 1. Principle of air classification of flour.

air deflects the particles into two fractions differing in size and density. In these experiments a Pillsbury laboratory model air classifier was used to separate the flour into a coarse and a fine fraction. The flours were separated into eight fractions by collecting a fine fraction, readjusting the classifier for a coarser cut, reclassifying the coarse fraction, and repeating the procedure until seven fine fractions and one coarse fraction remained. Classifier cut points were set to yield fractions with particle sizes (reported in terms of mass median diameter, that is, the diameter at which 50% of weight of sample is undersize) of about 11, 12, 15, 18, 21, 23, and 25 microns. Because of the large number of fractions taken and the intensive flour regrinding imposed, separations are near the maximum possible when using such a flour and this technique.

Yields and chemical analyses are given in Table 3 for air-classified fractions from triticale flours 131, 385 and 204. The triticale flours followed a pattern shown by all classes of wheat flour when air classified; namely, fractions with particle sizes below 15 microns had increased values of protein. Fractions 1-3 showed significant increases in protein content over that of the original flour. The highest protein content (34.3%) was found in fraction 1 from triticale flour 204. The finer fractions also contained higher fat and ash, and this feature appeared to parallel the higher protein contents.

The individual starchy or low-protein fractions 4 through 7 varied in quantity from 12% to 23% and in protein content from 4.4% to 6.8%. The coarse residues had essentially the same composition as the parent flours.

Total protein shift is the sum of the protein shifted into the high-protein fractions and out of the low-protein fractions, expressed as percentage of total protein present in the flour, as described by Gracza (14). In Table 4, fractionation results from classifying the three triticale flours are compared to those of a rye and three different types of wheat. The greater ease of fractionation of triticale 204 compared to triticales 131 and 385 is reflected in: 1) larger protein shift, 2) broader

Table 3. Fine grinding and air classification of triticale flours (14% moisture basis)

	Straight Grade Flour	Air Classification Fraction							
		1	2	3	4	5	6	7	8 (Coarse residue)
Triticale 204									
Yield, %	100.00	10.7	8.0	6.4	22.8	14.0	16.8	11.7	9.6
Protein, %	12.70	34.3	28.4	20.7	6.7	4.8	4.4	5.6	13.3
Ash, %	0.57	1.2	0.9	0.7	0.5	0.5	0.4	0.5	0.5
Fat, %	0.69	1.6	1.1	0.9	0.4	0.3	0.3	0.3	0.4
Triticale 131									
Yield, %	100.00	7.9	7.2	6.6	22.9	13.6	16.3	11.8	13.7
Protein, %	10.20	27.6	22.2	15.5	5.9	5.0	4.7	6.8	12.8
Ash, %	0.58	1.3	1.0	0.7	0.5	0.4	0.4	0.4	0.4
Fat, %	0.60	1.8	1.2	1.0	0.5	0.4	0.3	0.4	0.5
Triticale 385									
Yield, %	100.00	7.1	6.0	5.4	21.2	13.6	16.8	12.6	17.3
Protein, %	10.40	30.2	24.3	17.4	6.5	5.2	5.1	6.8	12.4
Ash, %	0.58	1.7	1.2	0.8	0.4	0.3	0.3	0.3	0.4
Fat, %	0.50	1.6	1.2	1.0	0.5	0.4	0.4	0.4	0.5

range of protein contents among the eight classified fractions, 3) higher yield of combined protein fractions 1 through 3 with higher protein content, 4) higher yield of combined starchy fractions 4 through 7 with lower protein content, and 5) lower yield of coarse residue. Analysis of Table 4 suggests triticale 204 behaved most like the soft wheat while triticales 131 and 385 were apparently somewhat more vitreous and behaved in a manner intermediate between soft and hard wheats.

Table 4. Comparison of fractionation responses of reground flours from triticale, rye (1), and wheat (2,3,4) (expressed as percent on 14% moisture basis)

					Wheat		
	Triticale			Rye,	Hard Red	Hard Red	Soft Red
Sample	204	131	385	Commercial Mix	Spring Selkirk	Winter Wichita	Winter Vermillion
Straight flour, protein	12.7	10.2	10.4	10.9	12.8	10.9	9.4
Maximum range of protein contents among eight classified fractions	34.3-4.4	27.6-4.7	30.2-5.1	21.5-6.2	23.7-7.6	29.4-5.5	26.7-2.3
Combined high-protein fractions 1-3							
Yield	25.1	21.7	18.5	25.8	18.8	21.0	29.4
Protein	29.0	22.1	24.5	19.8	19.4	24.4	21.4
Combined starchy fractions 4-7							
Yield	65.3	64.6	64.2	56.8	49.5	52.9	64.5
Protein	5.5	5.6	5.9	7.4	8.7	6.5	3.3
Coarse residue fraction 8							
Yield	9.6	13.7	17.3	17.4	31.7	26.1	6.1
Protein	13.3	12.8	12.4	9.6	14.2	9.8	6.2
Protein shifted, total	73.0	58.0	56.0	41.0	29.0	50.0	82.0

Classes and Composition of Proteins in Flour and Air-Classified Fractions. Both quantity and type of proteins affect grain structure and functional properties of flours. Table 5 compares the amounts of the different classes of proteins in flours from several grains. The data are a composite of results obtained at the Northern Laboratory by different isolation methods. Grains listed in Table 5 are arranged so that those that produce the strongest doughs and yield the toughest glutens appear at the top. The strong wheats yield the least quantities of albumins and globulins and the greater amounts of glutenins and acetic acid-insoluble proteins. In contrast, triticale and rye, which form weak glutens, have protein containing a high level of salt solubles, small amounts of gliadin component, and little acetic acid insoluble protein. The high levels of water soluble proteins (albumins and globulins) in rye and triticale contribute strongly to lysine content and result in overall nutritional protein qualities superior to wheat (15).

Table 5. Distribution of protein classes in wheats and other grains based on gel filtration separation

			Acetic Acid Soluble			
Type	Variety	Flour Protein (N X 5.7), %	Albumins and Globulins	Gliadin	Glutenins	Acetic Acid Insoluble
			Percent of Flour Protein			
Hard red spring semidwarf	Red River 68	12.7	12	25	25	33
Hard red winter	Ponca	10.7	15	29	27	22
Soft white winter	Brevor	9.5	17	26	24	25
Durum	Lakota	15.4	15	33	20	23
Triticale	FasGro 204	12.7	25	22	25	19
Rye	---	10.9	35	15	20	20

Amino acid patterns were determined for triticale 204 flour, and for the eight fractions after fine grinding and air classification (Table 6). The data show that lysine and leucine contents decrease from the finest fraction to coarse residue while methionine and phenylalanine increase. Contents of the other essential amino acids vary somewhat from fraction to fraction but show no particular trends. The higher values for lysine in finer fractions are probably due to a concentration of albumins and globulins.

Table 6. Amino acids in air-classified triticale 204 flour fractions
(g. amino acid per 16 g. nitrogen)

	Parent	Fraction							
Amino Acid	Flour	1	2	3	4	5	6	7	8
Lysine	2.5	2.6	2.3	2.5	2.3	2.4	2.3	2.2	1.9
Histidine	2.2	2.2	2.1	2.1	2.1	1.9	2.0	2.0	2.0
Ammonia	3.6	3.8	4.0	4.1	4.0	4.2	4.3	4.1	4.2
Arginine	3.9	3.9	4.1	4.1	3.8	3.5	3.7	4.2	3.4
Aspartic	4.9	4.4	4.1	5.6	5.3	5.8	5.6	5.2	4.1
Threonine	2.8	2.8	2.9	2.6	2.8	2.7	2.8	2.8	2.7
Serine	4.7	4.8	4.8	4.5	4.6	4.6	4.6	4.7	4.7
Glutamic	33.3	33.9	32.5	32.3	31.9	33.7	31.8	33.6	34.8
Proline	11.5	12.2	11.2	11.4	12.6	12.0	10.8	11.4	11.1
Glycine	3.6	3.6	3.4	3.5	3.4	3.7	3.5	3.5	3.3
Alanine	3.2	3.1	3.0	3.1	3.2	3.3	3.2	3.1	2.9
Valine	4.4	4.2	4.5	4.0	4.3	4.1	4.3	4.3	4.2
Methionine	1.4	1.3	1.1	1.2	1.6	1.2	1.5	1.7	1.6
Isoleucine	3.5	3.5	3.5	3.2	3.9	3.3	3.6	3.6	3.6
Leucine	6.9	7.0	6.4	6.5	6.3	6.7	6.3	6.4	6.4
Tyrosine	3.0	3.0	3.6	2.8	3.1	2.8	3.1	3.1	4.0
Phenylalanine	4.9	4.7	5.7	4.5	4.9	4.6	4.8	4.9	5.8

Wet Milling of Triticale 204 Flour. The proteins of cereals influence not only baking properties of flour but also milling characteristics and the nature of milled products. With growing interest both domestically and abroad in protein concentrates for food uses and with increasing use of starch for food and industrial applications, considerable attention has been directed to wheat and related grains as possible raw material sources. Triticale with its higher protein content is a potential source of gluten, and we investigated the isolation of triticale gluten by wet milling of flour.

A Martin-type process on a laboratory scale was used. The flour was kneaded to yield a dough ball which was washed to remove the starch. Since triticale yielded a soft, weak gluten ball, the dough could be worked only with care. Results of wet processing of triticale 204 are given in Table 7 and are compared with earlier reported (16) yields and characteristics of products from wheat flours. Yields of gluten and starch were comparable to those from wheat. Solids present in the process waters were 10% of the flour. These soluble solids contained 26% protein (MFB) and, if dried, have potential in foods, feeds, fermentation media or as a source of water-soluble proteins (albumins and globulins).

Table 7. Yields and analyses of wet-milled fractions from various flours (expressed as percent on moisture-free basis). Martin-type process.

Item	Triticale 204	Soft Winter Wheat	Hard Red Spring Wheat
Flour protein	14.7	14.2	16.4
Gluten yield from flour	17.0	14.0	17.8
Protein in gluten	70.0	80.0	78.0
Flour protein recovered in gluten	81.0	80.0	84.0
Lysine in gluten protein	2.3	1.9	1.6
Starch yield	69.0	71.0	70.0
Protein in starch	0.4	0.4	0.3

Amino acid analyses of triticale gluten, its parent flour, and grain are compared in Table 8. The leaching of water-soluble proteins from gluten during wet processing of the flour decreased lysine, valine and leucine but increased cystine, methionine, tyrosine and phenylalanine. Even though lysine content was lower in the gluten than in the parent flour or grain, it still is superior to the amount of lysine in wheat gluten. Triticale gluten also has a higher methionine content than wheat gluten, is softer in character, and possesses a bland flavor. These properties of triticale gluten offer interesting opportunities for its use in food. Growing requirements for fat emulsifiers, water-absorbing, and component-binding agents in prepared foods, and for nutritive supplements offer potential markets for use of glutens from triticale.

Further encouragement for industrial wet milling of triticale flours is based on the rather high yield, 69%, of low-protein starch (Table 7). The higher yields of grain claimed for triticale crops compared to those of wheat could result in a lower cost for triticale starch.

Table 8. Amino acid analysis of triticale 204 grain, flour, and gluten extracted from flour (g. amino acid per 16 g. nitrogen)

Amino Acid	Whole Grain	Flour	Gluten	Amino Acid	Whole Grain	Flour	Gluten
Lysine	3.3	2.5	2.3	Glycine	4.3	3.6	3.2
Histidine	2.3	2.2	2.4	Alanine	3.9	3.2	3.3
Ammonia	3.8	3.6	4.6	1/2 Cystine	1.1	1.4	1.6
Arginine	5.6	3.9	4.0	Valine	4.8	4.4	4.0
Aspartic	6.5	4.9	4.3	Methionine	1.2	1.4	1.5
Threonine	2.9	2.8	2.7	Isoleucine	3.6	3.5	3.4
Serine	4.7	4.7	4.6	Leucine	7.3	6.9	6.1
Glutamic	32.0	33.3	34.0	Tyrosine	2.8	3.0	3.9
Proline	9.5	11.5	11.8	Phenylalanine	4.6	4.9	6.4

Viscosity properties of triticale starch are compared to those of wheat and corn in Table 9.

Table 9. Amylograph viscosity patterns for triticale 204 starch and other starches

Starch	Pasting Temperature °C.	Brabender Units Peak Viscosity	Viscosity at 95°C.	Viscosity After Hold at 95°C.	Cold Paste Viscosity, 50°C.
Triticale 204	63	790	780	650	1230
Wheat	64	740	670	570	1000
Corn	68	1090	960	750	1470

Triticale starch had a slightly lower pasting temperature than either wheat or corn. The other viscosity characteristics of triticale starch fell between those of wheat and corn. From the standpoint of viscosity, it would appear that triticale starch could be used in similar manner to that of corn starch. Other workers have shown that triticale starch posses chemical and physical properties somewhat like those of its parents (17, 18) and should therefore be suitable for many current starch applications that the parents are.

Wet Milling of Whole Kernel Triticale. Triticale grain (204) was wet milled (19) in the laboratory. Grain was steeped in 0.3% sulfurous acid for 24 hr. at 100°F. then processed by milling, screening, and tabling. No particular problems were encountered; steeped grain was soft and ground quite readily. Coarse and fine fiber fractions, which also included the germ, were washed essentially free of starch with little difficulty. They contained less than 12% of starch after routine washing. Starch-gluten separation was typical of that encountered in wet milling wheat (Table 10).

Table 10. Comparison of starch recovery and analysis from conventional wet milling of triticale, wheat (19) and corn (20) (expressed as percent on moisture-free basis)

Starch	Triticale 204	Hard Red Spring Wheat	Soft White Winter Wheat	Corn
In whole grain	58.2	60.3	67.4	73.8
Processing data:				
Yield	41.2	38.9	50.5	65.4
Recovery[1/]	70.6	64.5	73.2	87.9
Protein content	0.27	0.27	0.24	0.5

[1/] Based on starch present in grain.

Yield of starch from triticale was 41.2%, similar to that from hard wheats. Soft wheat will generally yield more starch. Starch recovery (which is a measure of the ease of starch-gluten separation) was 70.6% in the triticale similar to that from wheat milling, but considerably less than that from corn milling. Purity of starch with respect to protein was excellent.

Conclusions. Triticale grain can be readily dry milled into flour, which can be further milled and air classified into fractions with desirable physical and chemical properties. Starch and gluten can also be recovered from triticale grain or flour by conventional wet processing. Triticale is a good potential source of protein-rich supplements for food products, as well as a source of flour and starch fractions for food, feed, and industrial applications.

Literature Cited

1. Unrah, A. M. and Jenkins, B. C. Investigations on synthetic cereal species, milling, baking, and some compositional characteristics of some "triticale" and parental species. Cereal Chem. 41:365-375, 1964.

2. Lorenz, K., Welsh, J., Normann, R., and Maga, J. Comparative mixing and baking properties of wheat and triticale flours. Cereal Chem. 49:187-193, 1972.

3. Lorenz, K. Food uses of triticale. Food Technol. 26(11):66-74, 1972.

4. Pomeranz, Y. Functional characteristics of triticale--A man-made cereal. Wallerstein Lab. Commun. 34(115):175-187, 1971.

5. Tsen, C. C., Hoover, W. J., and Farrell, E. P. Baking quality of triticale flours. Cereal Chem. 50:16-26, 1973.

6. Lorenz, K., Dilsaver, W., and Lough, J. Evaluation of triticale for the manufacture of noodles. J. Food Sci. 37:764-767, 1972.

7. Anderson, R. A., Stringfellow, A. C., and Griffin, E. L., Jr. Preliminary processing studies reveal triticale properties. Northwest. Miller 279(2):10-13, 1972.

8. Wall, J. S., Bietz, J. A., Huebner, F. R., Anderson, R. A., and Stringfellow, A. C. Effect of variety and processing on wheat and triticale proteins. Proceedings 7th National Conference on Wheat Utilization Research, November 3-5, 1971, Manhattan, Kansas, U.S. Department of Agriculture, ARS-NC-1, p. 119-135, July 1972.

9. Miller, D. F. Composition of cereal grains and forages. Nat. Acad. Sci., Nat. Res. Counc. Publ. 585:9, 14-17, 1958.

10. American Association of Cereal Chemists. Approved Methods, Revised. The Association, St. Paul, Minn. 1971.

11. Peplinski, A. J., Stringfellow, A. C., and Griffin, E. L., Jr. Air classification response of durum and hard red spring wheat flours. Northwest. Miller 272(5):34, 36-37, 1965.

12. Stringfellow, A. C. and Peplinski, A. J. Air classification of Kansas hard red winter wheat flours. Northwest. Miller 270(6):19-20, 22; 1966.

13. Peplinski, A. J., Stringfellow, A. C., and Griffin, E. L., Jr. Air classification of Indiana, Ohio, and Michigan soft wheat flours. Northwest. Miller 271(2):10-12, 1964.

14. Gracza, R. The subsieve-size fractions of a soft wheat flour produced by air classification. Cereal Chem. 36:465-487, 1959.

15. Chen, C. H. and Bushuk, W. Nature of proteins in triticale and its parental species. I. Solubility characteristics and amino acid composition of endosperm proteins. Can. J. Plant Sci. 50:9-14, 1970.

16. Knight, J. W. Chemistry of Wheat Starch and Gluten and Their Conversion Products. Leonard Hill, London, 1965.

17. Berry, C. P., D'Appolonia, B. L., and Gilles, K. A. The characteristics of triticale starch and its comparison with starches of rye, durum, and HRS wheat. Cereal Chem. 48:415-427, 1971.

18. Klassen, A. J. and Hill, R. D. Comparison of starch from triticale and its parental species. Cereal Chem. 48:647-654, 1971.

19. Anderson, R. A. Wet milling properties of grain: Bench-scale study. Cereal Sci. Today 8(6):190-192, 195, 221; 1963.

20. Slotter, R. L. and Langford, C. T. Wheat starch manufacture, Ind. Eng. Chem. 36(5):404-408, 1944.

A CLOSE LOOK AT WHAT HAPPENS WHEN WATER IS ADDED TO WHEAT PARTICLES

J. E. Bernardin
Western Regional Research Center, Agricultural Research Service,
U.S. Department of Agriculture

Nearly all uses of wheat involve the wetting of endosperm tissue during one stage of the processing. However, little is known about the detailed reaction of wheat endosperm with water or about the physical properties of the protein, starch, and other cellular organelles once wet. We have studied the wetting of unfixed sections and particles of wheat endosperm while continuously recording the changes that occur on videotape.

Endosperm sections from wheat kernels react rapidly with water, transferring the entire contents of endosperm cells to the aqueous phase wherever endosperm cell walls are broken. Cutting the endosperm cell wall at the end of the cell and exposing the cellular contents to water is sufficient to initiate the dispersion of the cell contents. Small fibrils of protein stream rapidly into the surrounding solution. The initial fibrils quickly develop into a linked network of fibrils as more protein is pulled from the cell and rapidly expand the volume of solution they occupy. The rate of expansion slows gradually, but frequently continues until the entire contents of the cell are dispersed into the solution. The three-dimensional web of protein thus produced is highly interconnected, and a break in one fibril is reflected throughout the network. Starch granules, large and small, adhere to the surface of the fibrils. Fibrils which develop from the protein in the interior of the cell are frequently highly linked to those adjacent, resulting in a high density of fibrils. This linked web apparently results from the dispersion of the protein in a fibrillar form from the matrix protein deposits in the endosperm (Figure 1).

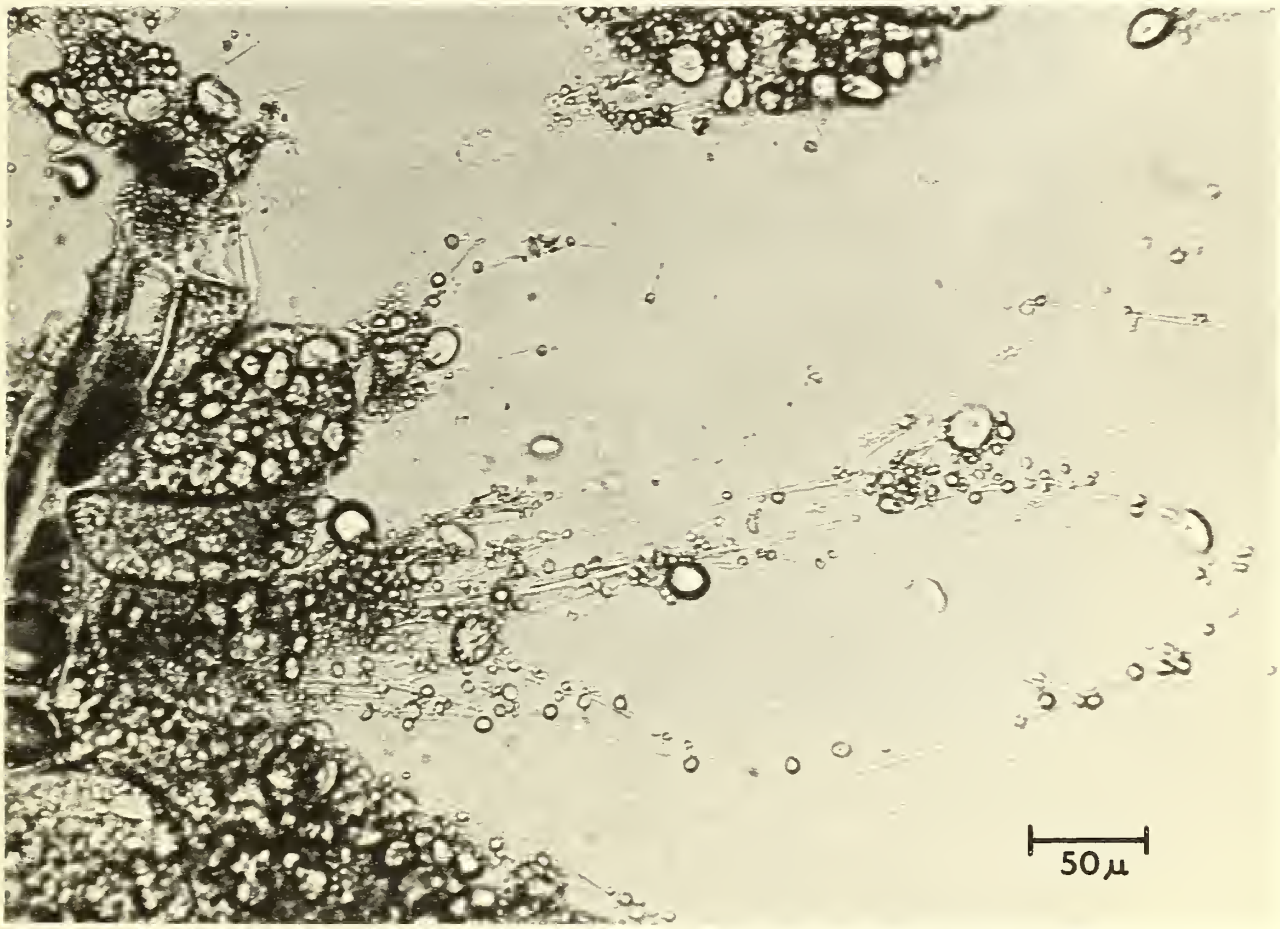


Figure 1. A section of wheat endosperm wetted by a drop of water showing the dispersion of protein fibrils into the aqueous solution. One cell wall was cut by sectioning and the cellular contents spread into the solution while an adjacent cell was not cut and the cell wall is holding back the contents.

Regardless of the location of the endosperm cell within the kernel, the reaction and apparent extent of fibril formation remain the same. It is apparent that fibril elongation through flow and elastic stretching results from the viscous drag of the solution flowing away from the endosperm particle. This solution flow is rapid as indicated by rates of flow of free starch granules (100 microns per second) and must be convection currents generated within the water drop. The fibrillar properties of the hydrated protein are the phenomena to be considered in this paper, not the rapid solution flow away from the endosperm particle.

Identical results to those obtained with thin kernel sections are obtained with flour particles; fibrils form in all directions from the particles. The flow, and consequently the drawing out of the protein fibrils, can be restricted by high flour concentrations or any physical obstruction, such as covering the flour particles with a cover glass; the protein fibrils in the hydrated flour particles are readily seen by mechanically spreading the tissue with a microprobe. This demonstrates that the protein fibrils are not artifacts of the aqueous reaction in dilute solution. Once formed, the fibrils are very slow to dissolve and will persist in suspension for several hours.

The fibrils become smaller in diameter as elongation proceeds. If the solution flow is sufficiently rapid and viscous flow in the fibril is insufficient to relax the applied stress, the fibril breaks and exhibits an elastic component in the deformation. The elastic recovery may account for as much as 20% of the fibril elongation. The elastic component in the deformation decays but may not reach zero, as evidenced by fibrils that break after all apparent flow has stopped, yet still show elastic recoil of the broken ends. Furthermore, there is no retraction of the fibrillar web once it has formed, even though all flow has stopped.

All of the wheat endosperm protein seen in the light microscope exhibits these properties. Triticale and rye form fewer fibrils than wheat and are also the only other cereal grains which have any capacity to form a dough similar to wheat dough. No tendency for fibril formation was observed in corn, rice or barley endosperm sections. Similarly, isolated wheat starch shows no tendency toward fibril formation, even though some protein may remain on the surface of the starch granules.

There is an interaction between the starch fraction and the protein fibrils as evidenced by the adherence of starch granules to the surface of the fibrils. The forces exerted on the starch granules by the flowing solution may contribute to the drawing out of the protein fibrils. In cases where a fibril is observed to break and recoil elastically, a starch granule may be dislodged from the fibril and float free in solution even though other granules on the same fibril remain adherent. This variation in the strength of interaction between the starch granules and protein fibrils may only result from a variation in surface contact area. There does appear to be a difference in the degree of interaction between the protein fibrils and large and small starch granules. This difference may be the result of the envelopment of the large granules with the amyloplast membrane while the small granules may have only remnants of the membrane remaining on their surface or, no amyloplast serving as an interaction medium. While starch acts as a filler in the dough system, the interaction of the starch granule with the protein fibrils indicates that the starch granule surface characteristics should affect the uniform dispersion of the starch in the protein fibril matrix. Any change in the starch granule surface characteristics which would weaken the adherence of the granules to the protein fibrils would probably decrease the uniformity of the final texture that is desired in baked goods.

Flour hydration occurs very rapidly. Wetting a single particle of flour in a droplet of water requires less than 0.05 seconds for complete hydration as measured by the initiation of fibril formation. Within 5 seconds the hydrated protein web spreading from the particle reaches its maximum volume with a 20-fold or greater increase over that of the initial particle. Adjacent flour particles spreading similar protein networks interact to form a continuous interacting system that can be worked mechanically to form a doughlike mass.

When the protein fibrils are fixed by rapid freezing and then freeze-dried, the fine structure of the fibrils and their interactions with starch can be examined. The greater resolving power of the scanning electron microscope as compared to the light microscope demonstrates that there are finer and many more fibrils than can be seen in the light microscope. The surface characteristics of the fibrils are also visible. Rather than continuous strands of drawn out protein, the fibrils appear to be drawn out from sheets of protein (Figure 2) and have torn fragments of the sheets along their length. Some of these fragments may provide interaction sites for the starch granules. Fibril interaction with the surface of the starch granules may involve only a small portion of the starch surface or it may nearly envelop the granule.

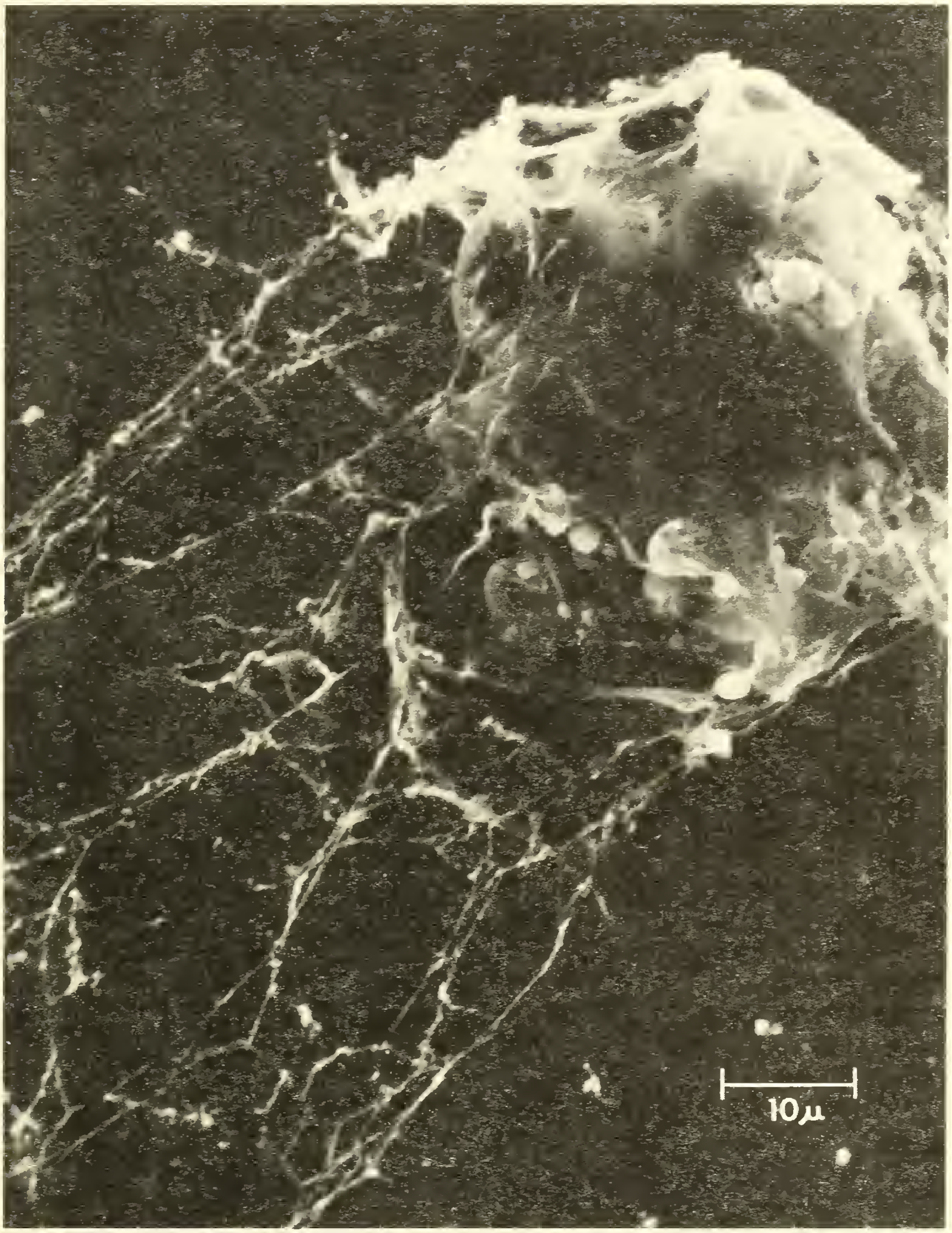


Figure 2. A scanning electron micrograph of a flour particle which had been wet but was then frozen and lyophilized. Sheets of protein in the intact flour particle are pulled by the currents within the drop. The stresses first generate holes within the protein sheet which become so extensive that finally all that remains are fibrils of protein.

WHOLE WHEAT FRACTIONATION PROCESS

Wayne Henry and G. V. Rao
FAR-MAR-CO., INC.

Over two hundred years ago, in 1745, Beccari reported the separation of gluten from wheat flour. It thus became the first plant protein to be isolated. Wheat gluten and its components have been systematically studied for several decades. Gluten is a complex system. Therefore, it is not surprising that different workers using different approaches and equipment are not always in full agreement on the interpretation of the results. The commercial manufacturing process for gluten, however, has remained essentially the same for many years.

Basically, wheat can be divided into three major fractions: Endosperm, (starch and gluten) 85%; bran, 13%; and germ, 2%. The most valuable fractions of the wheat kernel are germ, because of its high protein and fat content and vital wheat gluten because of its unique characteristics and properties. For the manufacture of wheat starch and wheat gluten the endosperm is the critical fraction. Historically, the starting material for gluten manufacture has been second clears, a by-product of conventional flour milling. Improvements in milling techniques coupled with a drastic decline in the number of operative flour mills had lead to current shortages of and high prices for second clears. In fact, many million pounds of vital wheat gluten are imported by the United States from such places as Germany, Japan, Australia, and Canada, each year just to meet the demands domestic producers cannot fill.

Traditional Gluten-Starch Separation Processes. The traditional processes involve milling wheat to flour; hydrating the flour to develop the gluten, separating the starch and gluten by washing with water, and refining the separated starch and gluten products. There are three commercial processes that use this traditional approach: the Martin process, the batter process and the continuous batter process. They all depend on manipulating a flour-water dough in an excess of water to remove starch and other materials from the vital (elastic) wheat gluten.

The oldest method for the preparation of starch and gluten is the Martin process developed in Paris in 1835 (Figure 1). This process involves making a stiff dough containing approximately 60 percent water. After hydration, the dough is rolled between fluted rolls or kneaded in a trough with reciprocating rolls under water at high pressure. The starch is washed away and a coherent mass of high protein gluten remains.

The batter process was developed by the United States Department of Agriculture in 1944 (Figure 2). The Martin and the batter processes differ in the way gluten is handled. In the Martin process, gluten is maintained as a single coherent mass and the starch is washed away from it. In contrast, the batter process is designed to disperse the dough in water and then to recover the gluten lumps on a screen.

A continuous version (Figure 3) of the batter process was developed by the United States Department of Agriculture in 1958. The process involves feeding flour and water continuously at controlled rates to a mixer. After a short aging period, the batter is fed directly into a cutting pump followed by water washing on a shaker screen. The continuous process yields quality product, is amenable to instrumentation, and has minimum requirements for labor, power, and water.

Other processes in addition to the Martin, batter, and continuous batter processes have been occasionally used or described in the literature but are not discussed here. All of the processes reviewed, however, used flour or clears as starting material for the production of starch and vital gluten.

FAR-MAR-CO Whole Wheat Fractionation Process. About three years ago FAR-MAR-CO., INC., initiated a research project with an overall objective of increasing the industrial utilization of wheat. Findings to date have justified the finding of three processes and five product patents. Some information on the process(es) is proprietary and cannot be revealed at this time, however, the general nature of the primary process of concern here is shown in Figure 4.

The new process was developed to separate vital gluten, starch, bran, and germ from whole kernel wheat with minimum damage to the functional, chemical or biological values of these components. The technical feasibility of this process has been demonstrated by erecting a small scale front-end pilot plant. The data obtained from our front-end pilot plant was used to design and specify equipment for a larger plant that is now under construction and will have the capabilities of processing 1,000 to 2,000 pounds of wheat per hour. If all goes well the plant will be ready to start at the end of 1973.

The first step of the present process comprises tempering or hydrating the whole wheat kernel in water, with mixing, to achieve a moisture content by weight of 15 percent. The tempered wheat is flaked by a conventional roller mill. Flaking the tempered wheat is one of the critical steps in this process. If the rolls are set too close, there will be damage to germ, bran, and starch. Too thick flakes adversely affect the yields and create difficulties during processing. The flakes are hydrated by addition of known amount of water and mixed in a continuous mixer. Hydration of the flaked kernel is

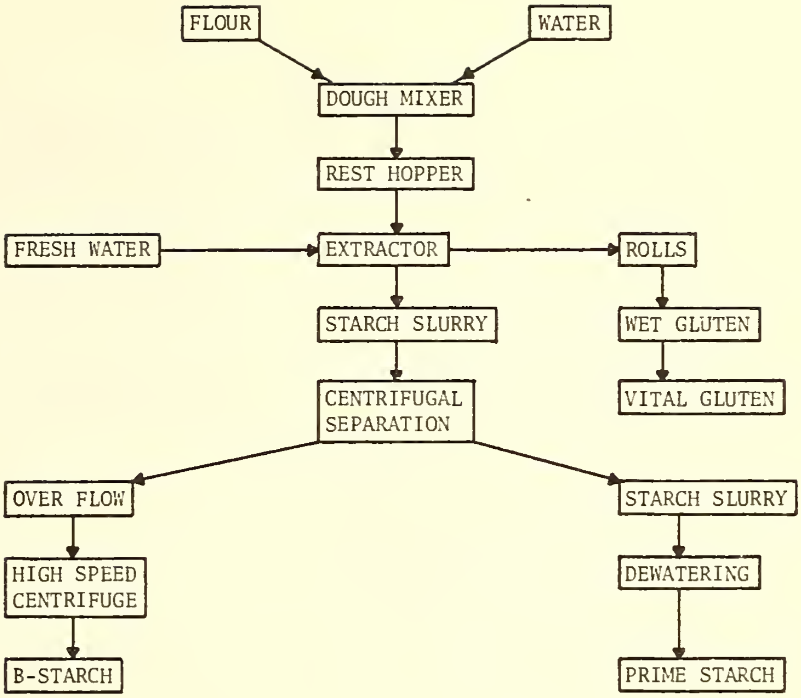


Figure 1. Simplified flow diagram for Martin process for manufacture of gluten and starch from wheat flour.

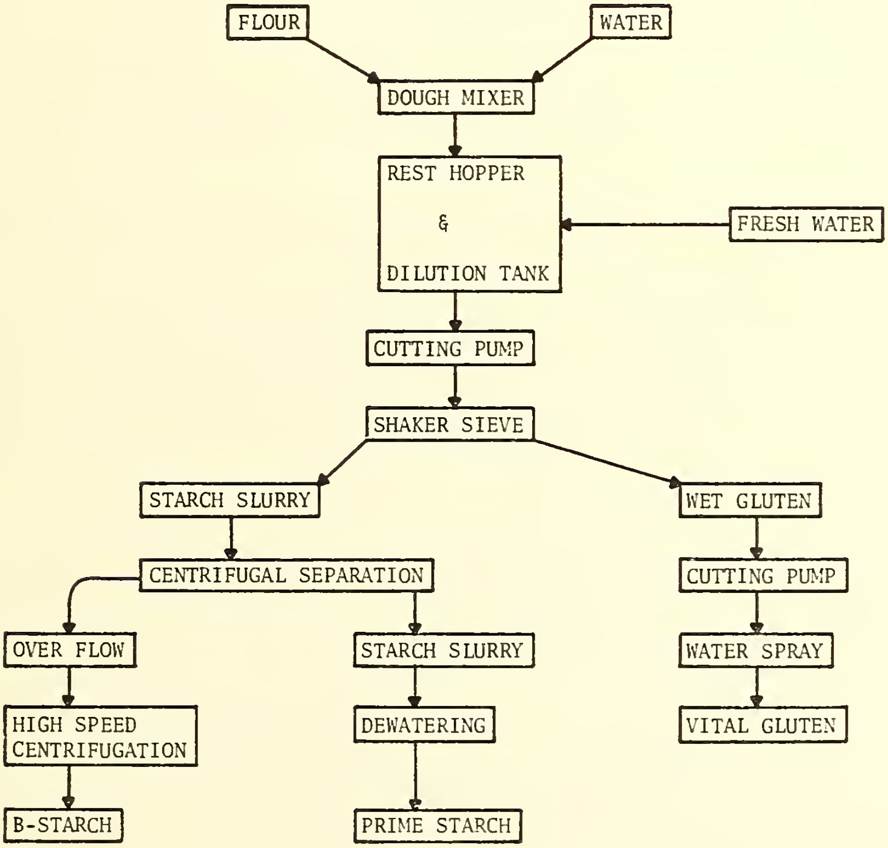


Figure 2. Simplified flow diagram for batter process for manufacture of gluten and starch from wheat flour.

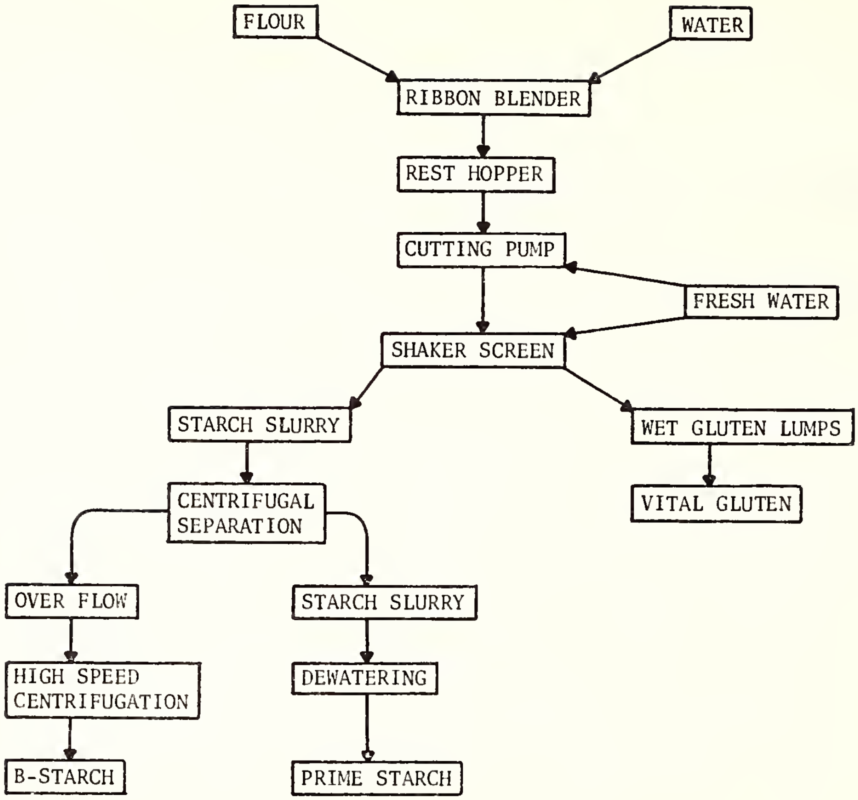


Figure 3. Simplified flow diagram for the continuous batter process for manufacture of gluten and starch from wheat flour.

also an extremely critical step in the present process. The extent of hydration is the key which allows effective component separation from the flaked whole wheat kernel. The flakes are hydrated with limited quanitites of water to a point where a thick, dough-like mixture is formed having no excess of water.

Separation of the thick, dough-like mass into its components, is accomplished by mechanically working the mass while it is partially or completely submerged in water followed by water washing through high pressure spray nozzles. For this purpose a preferred manner of manipulation is to place the hydrated flakes in a rotary screen or drum-type separator having internal flights and lifters to convey the product along the horizontal axis of the rotating screen. As the screen or drum rotates, the hydrated flakes are mechanically manipulated; the starch, bran-germ, and other non-gluten components are washed leaving hydrated elastic gluten in the screen. The washings are passed through the perforations into a holding tank for subsequent separation and purification.

Final purification of gluten is achieved in a gluten extractor designed by FAR-MAR-CO. Vital wheat gluten obtained after purification and drying has 82-85 percent protein. The remaining water washing in the rotary screen is filtered through a series of screen and centrifuges to obtain prime starch and bran-germ mixtures. Residual bran-germ mixture is further separated into its components by specific gravity separation.

Our process and the use of the whole wheat kernel as a starting material has distinct advantages. Essentially all of the gluten in the wheat kernel is recoverable. The starch obtained from our process has minimum damage when compared to starch processed by conventional processes. The conventional process of milling wheat and the production of second clears does considerable damage to the starch granules. Moreover, the whole wheat kernel offers a stable supply of raw material with dependable and predictable physical and chemical characteristics. In addition, processing whole wheat kernel produces a greater yield of high quality vital gluten and starch per bushel of wheat processed. Our initial

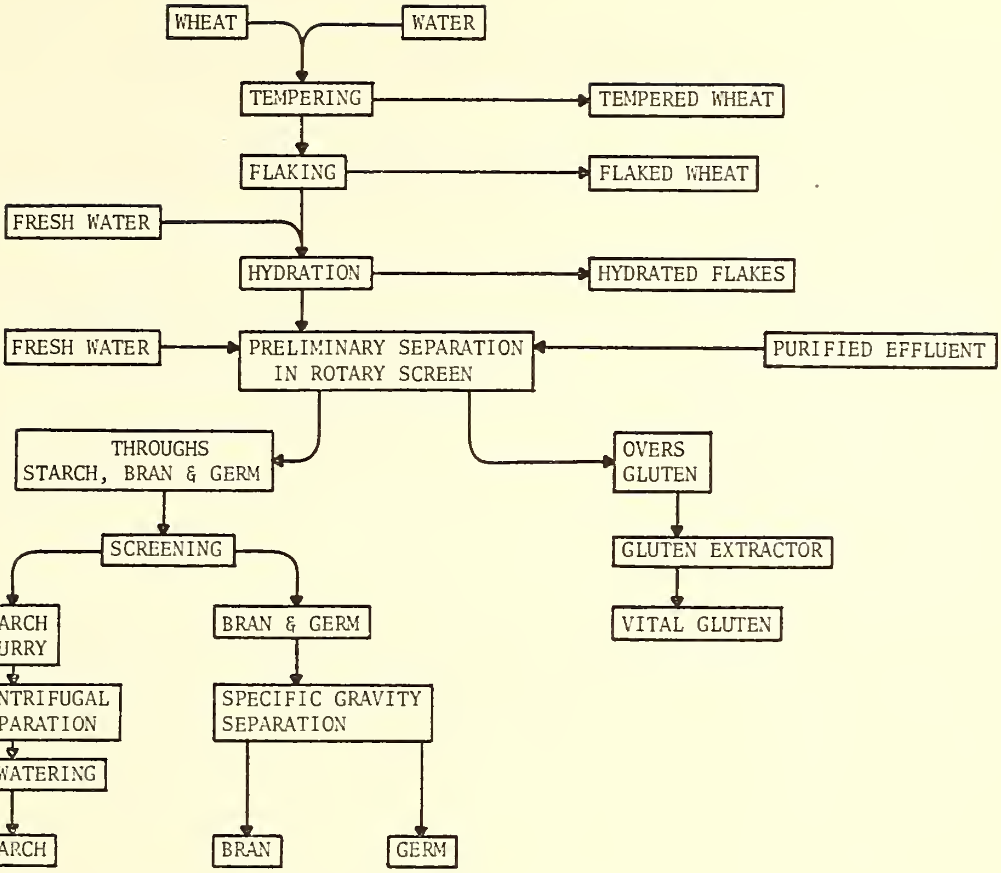


Figure 4. FAR-MAR-CO, Inc., whole wheat fractionation process.

yield figures indicate that we can recover 95% of the starch, 97% of the vital wheat gluten and 80% of the solubles.

At this point we believe the process is technically sound and economically feasible. Therefore, FAR-MAR-CO is in the final construction phase of a rather large pilot plant. Process data from the pilot plant operation coupled with customer response to the products will yield the necessary economic data to plan the construction of production facilities. The plant will have the capabilities of processing approximately 1 to 2 thousand pounds of wheat per hour. From a thousand pounds of wheat per hour approximately 90 pounds of vital wheat gluten, 620 pounds of starch (virtually all prime starch), 30 pounds of germ, and 120 pounds of bran can probably be recovered. Actually the pilot plant, operating around the clock, could be considered a semi-works plant. The plant would produce approximately ½ million pounds of gluten per year.

Second FAR-MAR-CO Whole Wheat Fractionation Process. Information on another approach to wheat fractionation is revealed in the FAR-MAR-CO Patent Application, "Extraction Process for Preparation of Vital Wheat Gluten From the Whole Wheat Kernel" (U.S. Ser. No: 391,635). This is a two-stage extraction process for the preparation of vital wheat gluten, starch, and bran-germ. The whole wheat kernel is tempered then crushed, flaked, or ground and the lower molecular weight proteins are extracted with water below pH 8.0. Bran-germ is separated by sieving and the gluten-starch residue is centrifuged from solutions. The higher molecular weight proteins are extracted from the residue in an aqueous solution above pH 8.0 (preferably ammonium hydroxide) yielding a higher molecular weight protein fraction and starch.

Use of low molecular weight fraction is highly recommended in nutritional fortification. It has a higher percentage of essential amino acids and other nutrients when compared with the other fraction. Additional uses of this fraction includes foaming, whipping, and dispersing agents. High molecular weight fractions obtained in this process are essentially vital gluten. Various food and non-food uses of this fraction as is or after modification includes bakery products, HVP, milk-like products, surfactants, detergents, plasticizing agents, films, adhesives, and water absorbants.

PREPARATION AND PROPERTIES OF PROTEIN CONCENTRATES BY WET-PROCESSING WHEAT MILLFEEDS

R. M. Saunders, A. A. Betschart, M. A. Connor, R. H. Edwards, and G. O. Kohler
Western Regional Research Center, Agricultural Research Service
United States Department of Agriculture

The search for protein sufficiency has stimulated investigation of many unusual sources of protein but little investigation has been carried out on the most readily available protein source, cereal grains. At the present time cereal grains represent the most plentiful and most economical source of protein suitable for man's needs.

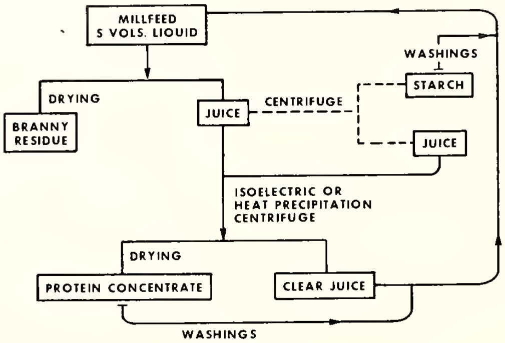
This paper will illustrate a technique whereby protein concentrates can be manufactured from wheat milling by-products by a wet process. A few years ago the mere mention of such a wet process would have been viewed unfavorably but with the ongoing installations of plants to wet process whole wheat, the system described here would be merely a tangential step in the overall process. Moreover, it is a step whereby products of high nutritional value would be manufactured either for animal feed or human food.

When wheat is milled for flour, a complex series of roller mills and sifters is used to separate out the maximum amount of flour, consisting of at least 72% of the wheat kernel. The remaining percentage of the kernel is the wheat millfeed, consisting of bran, middlings (or shorts in southwest U.S.), red dog, and germ. The specific type of millfeed produced depends mainly on the local market demand. In the U.S., the bran and middlings generally predominate, except on the West Coast where millrun (the total unfractionated millfeed) predominates.

Nearly 5 million tons of millfeeds are produced annually in the U.S. The vast majority is used in animal feeds, mainly ruminants, but represent no more than 10% of the total ingredients used by the formula feed industry, and no more than 5% of the total volume of feed consumed (1). The high fiber content of millfeeds prevents their more widespread use in human food. Analyses reveal that millfeeds are rich in high-quality protein, fat, vitamins and minerals. However, the actual protein digestibility (2) and fat availability (3) in millfeeds is only in the order of 60-80% of the theoretical values for monogastric animals, which presumably would apply to humans. Yet, the protein nutritive value is clearly superior to wheat flour protein (4), the fats are about 70% unsaturated, and the vitamins and minerals are at high levels (5), all desirable qualities for human foods.

Fellers et al. (6) demonstrated a wet alkaline process which could be used to extract protein from wheat bran. Our objective has been to devise a process whereby the rich source of nutrients can be separated from the undesirable fibrous residue of millfeeds and concentrated to a highly nutritious product.

Process. A flow sheet describing the process is shown in Figure 1. Basically the process involves mixing the millfeed with five volumes of water and/or recycled clear juice, adjusting the pH to 8.6 and mixing for 15 minutes. The mixture is then squeezed to separate the alkaline juice extract from the fibrous residue. The residue contains about 40% solids and would be dried for animal feed. The juice can be subjected to either of two processes depending on the particular product demand. In one process,



WET-PROCESSING OF WHEAT MILLFEED:
CONTINUOUS BATCH EXTRACTION PROCESS

Figure 1. Wet process for manufacture of protein concentrate from wheat millfeeds.

the pH is lowered to 6.0, steam is injected to attain a temperature of 85°C and the precipitated protein concentrate is centrifuged or filtered; alternatively, the pH is lowered to pH 4-5, and the protein concentrate is collected by centrifugation. In both methods, the products may be washed. In the second process, the juice is first centrifuged to precipitate starch as a separate product. The mother-liquor is then treated as in the first process. From each process, the final mother-liquor or "clear juice" plus any washes are then recycled to the next batch of millfeed and the process is repeated.

Yield and Composition of Protein Concentrates. The yield of protein concentrate from shorts as a function of pH and mixing time is shown in Figures 2 and 3. From this data, a condition of 15 minutes mixing time and a maintained pH of 8 to 9 was selected and employed in future work except where indicated.

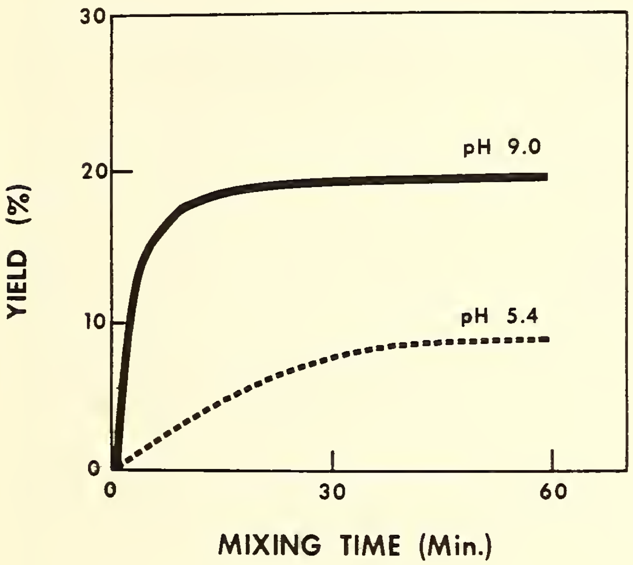


Figure 2. Effect of mixing time at pH 9 or 5.4 on yield of protein concentrate from shorts.

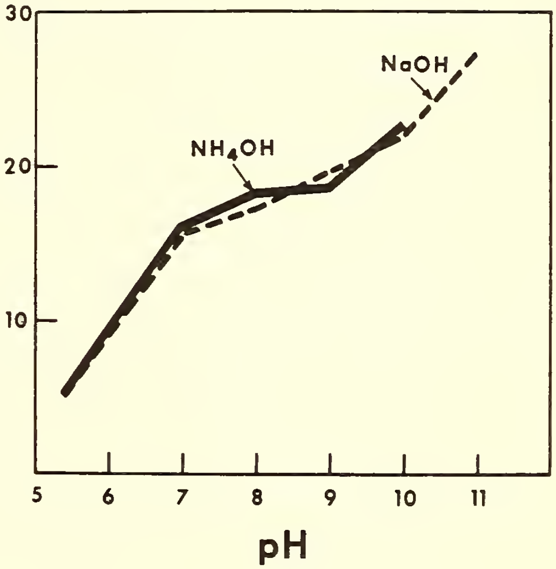


Figure 3. Effect of pH on yield of protein concentrate; mixing time was 15 minutes.

The yield and composition of protein concentrates obtained from wheat bran, wheat millrun and shorts by wet processing are shown in Table 1. Highest yields with highest protein content were obtained from shorts. Increase in extraction pH increased yield and protein content somewhat. The yield and composition of products prepared at pH 8.6 from wheat shorts, where the starch has been removed during the process, is also shown in Table 1. In addition, the product obtained by subsequent defatting is described. Production of a wheat oil by this process may be attractive since the oil is highly unsaturated and contains a large quantity of natural antioxidant. It is apparent that products with varying contents of protein, starch and fat can be prepared normally in yields of 9 to 25% from wheat shorts, bran and millrun.

Starch, Residue and Juice. The question arises; what about the separated starch, clear juice and pressed residue, what is their potential? Table 2 shows the composition of these side-products in the case of wheat shorts. The sugars in the clear juice are mainly glucose, fructose, sucrose, raffinose, neokestose, and maltose. During recycling the solids level of the clear juice increases but quickly reaches an equilibrium level. The high sugar content after concentration would make it suitable for an animal feed supplement or a growth medium for cellular organisms. After drying, the composition of the residue is similar to wheat bran, except that it is low in fat. The starch could easily be purified further if desired.

Other Characteristics of the Protein Concentrates. The protein concentrates are light tan colored. Their theoretical metabolizable energy (ME) value for chicks, calculated by the method of Carpenter and Clegg (7) is high. For example, the calculated ME of the protein concentrate containing starch prepared from shorts at pH 9 on a dry basis is 1987 Kcal/lb. This value compares favorably with present commercial feeds for broilers such as fish meal and soybean meal which have ME values for chicks of 1450 and 1150 Kcal/lb, respectively.

The concentrates contain a high level of natural antioxidant. The structure of the prevalent antioxidant in our protein concentrates has been established to be an alkyl resorcinol. This work is as yet unpublished and was done by Dr. H. J. Burkhardt at WRRL. It is estimated that this component is present in the millrun protein concentrate at not less than 0.03% by weight. Protein concentrates prepared by the wet process are very stable. Little sign of rancidity as judged by odor could be detected after several months storage at room temperature.

Table 1. Yield and composition of protein concentrates from various millfeeds at different pH values; heat or acid precipitated products. Yields are on starting millfeed as is basis

Starting material and conditions	Yield %	Solids %	Protein (N X 6.25) %	Fat %	Fiber %	Ash %	Starch %
Wheat Bran							
pH 9, heat	12.1	93.0	32.3	8.9	0.7	6.1	37.8
Wheat Millrun							
pH 8, heat	15.8	93.3	25.4	7.2	0.7	4.2	46.0
pH 9, heat	17.3	93.5	24.5	6.5	0.8	3.8	44.6
pH 9, acid	15.1	92.3	25.9	8.2	0.5	1.8	56.6
Wheat Shorts							
pH 8, heat	17.3	94.8	33.4	6.5	0.4	4.8	--
pH 8, acid	18.8	96.0	29.7	--	--	--	--
pH 9, heat	19.3	93.8	32.9	10.4	0.4	3.7	34.2
pH 9, acid	19.2	95.5	36.9	--	--	--	--
pH 10, heat	21.7	93.8	38.2	10.2	0.3	3.8	36.0
pH 10, acid	21.4	97.0	36.9	--	--	--	--
pH 11, heat	27.5	95.5	40.3	9.7	0.4	4.9	34.2
pH 9, heat and washed	16.2	97.4	40.0	9.7	0.5	2.0	45.8
pH 8.6, starch removed before heat pptn.	9.7	97.7	63.8	17.3	0.5	3.4	--
pH 8.6, starch removed before heat pptn., defatted	--	94.7	75.4	0.7	0.4	3.8	--

Table 2. Yield and composition of pressed residue, clear juice, and starch produced during wet processing of wheat shorts at pH 9

Material	Yield %	Solids %	Protein (N X 6.25) %	Fat %	Fiber %	Ash %	Starch %	Sugar %
Pressed residue (dried)	63.7	88.9	14.1	1.3	13.2	4.0	12.6	--
Starch (dried)	6.8	97.0	3.8	0.4	0.4	5.2	86.2	--
Clear juice (dried)	16.0	95.0	17.0	--	0	8.0	0	44.0
(As recovered)	--	4.0	--	--	--	--	--	--

Trace minerals are also concentrated in these products. Table 3 shows a mineral pattern obtained by X-ray fluorescence analysis by Dr. William Reuter at WRRL.

Table 3. Minerals (ppm, ± 10%) in protein concentrate from wheat shorts by wet processing at pH 9; heat or acid precipitated products

Element	Protein concentrate		Literature values (8) for:	
	Heat	Acid	Wheat shorts	Wheat flour
Mn	309	16	91-142	2.1-3.5
Fe	369	301	38-79	3.5-9.1
Cu	44	76	7.7-14	0.62-0.63
Zn	208	39	62-141	3.4-10.5

It must be emphasized that the data is preliminary and needs to be investigated further, particularly the extremely high iron content. Compared to wheat flour the protein concentrates are very rich in minerals. Their incorporation into wheat flour mixes would be beneficial from the trace element standpoint.

Protein Nutritional Quality. The nutritional potential for these products has already been implied by their composition. In a feeding study with rats, protein digestibility and PER have been measured. Table 4 summarizes part of this work.

Table 4. Protein digestibility and PER value of protein concentrates (PC) from wheat millrun by wet processing at pH 8.6 compared to casein and other wheat products

Determination	PC-I Freeze-dried	PC-II Drum-dried	Millrun	Bran	Shorts	Flour	Casein
Protein Digestibility, %	92.5	92.1	72.5	73.0	77.4	93.2	99.8
PER	1.99	1.88	1.86	1.74	--	0.73	2.50

The high digestibility and satisfactory PER provide encouragement for the process. For comparative purposes the equivalent figures for shorts, bran, millrun and flour are included.

The protein concentrates are high in lysine. In general, they contain 5.0 g/16 g N as compared to 4.2 for shorts, 4.1 for bran, and 1.9 for flour. Considering these desirable nutritional attributes, the concentrates could well find use in poultry rations and in weaning rations for calves and pigs.

Protein Solubility Profile. If protein concentrates are to gain acceptance as human foods they must possess desirable functional properties as well as provide nutritional value (9). The nitrogen solubility of a laboratory preparation of wheat protein concentrate, acid precipitated at pH 5.0, was studied at pH values of 1.6 to 10.0 (Figure 4). Maximum solubility was attained at pH 1.95 - 2.0 and 10.0 where 80% or more of the nitrogen was soluble. Minimum solubility, i.e., 14-16% was observed at pH 4.8 to 6.4

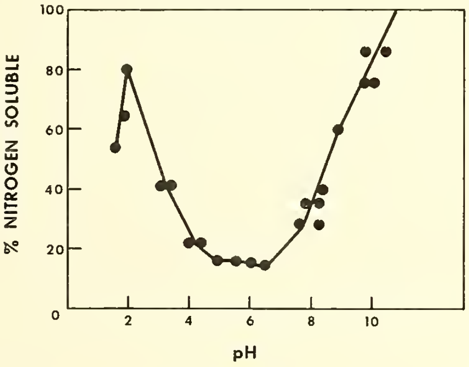


Figure 4. Nitrogen solubility of an acid precipitated protein concentrate as affected by pH.

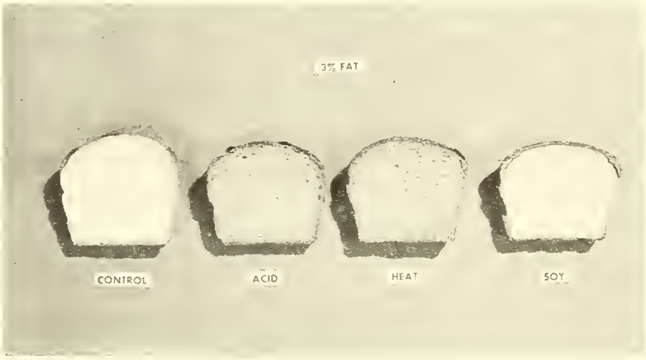


Figure 5. Breads fortified with 10% wheat protein concentrate (heat or acid precipitated) or defatted soy as compared with standard white bread.

Use in Bread. Wheat protein concentrate (heat precipitated, drum dried) has been successfully incorporated into pup loaves at levels of 10% of the flour (Figure 5). Protein content of the final baked product was increased 35% over the flour control. As shown in Table 5, the volumes of the loaves made with protein concentrate trended higher than the soy control but slightly less than the wheat flour control. Characteristics such as break and shred, grain, and texture of the experimental loaves compared favorably with both of the controls. Thus, the protein content of bread can easily be increased by incorporation of wheat protein concentrate.

Future Research. Additional research is needed to refine the process, define and characterize specific products, and determine economic feasibility. Current efforts at WRRL include: 1) Improvement of yield through process modifications, 2) Control of compositional aspects, 3) Development of products

Table 5. Preliminary baking studies. Incorporation of protein concentrate compared to soy into wheat flour bread; 3% fat in bread formulation

Bread-type	Volume (cc)	Break & Shred (Score 5)	Grain (Score 15)	Texture (Score 15)
Wheat flour control	695	3.25	12.5	13.0
Soy, 10% level	618	2.5	13.0	13.0
Concentrate 10% level, heat ppt drum-dried	650	3.0	12.5	13.25

with high metabolizable energy for non-ruminant feeds, 4) Development of products with desirable functional properties suitable for use in foods, 5) Development of a stable, highly unsaturated wheat oil product, 6) Determination of trace mineral and vitamin content, 7) Evaluation of economics, and 8) Application of the process to other cereal grain by-products. For example, this wet process works well on full fat rice bran, rye and triticale brans, and brewers spent grains.

Literature Cited

1. Shellenberger, J. A. Nutritional values of wheat and wheat by-products as affected by modern production and milling techniques. In: Wheat in Livestock and Poultry Feeds, OSU, Stillwater, Oklahoma, pp 34, 1970.

2. Saunders, R. M., and Kohler, G. O. In vitro determination of protein digestibility in wheat millfeeds for monogastric animals. Cereal Chem. 49:98, 1972.

3. Saunders, R. M., Walker, H. G., and Kohler, G. O. Aleurone cells and the digestibility of wheat millfeeds. Poultry Sci. 48:1497, 1969.

4. Miladi, S., Hegsted, D. M., Saunders, R. M., and Kohler, G. O. The relative nutritive value, amino acid content, and digestibility of the proteins of wheat mill fractions. Cereal Chem. 49:119, 1972.

5. MacMasters, M. M., Bradbury, D., and Hinton, J. J. C. Microscopic structure and composition of the wheat kernel. In Wheat: Chemistry and Technology (ed. by I. Hlynka). American Assn. of Cereal Chemists, St. Paul, Minnesota, pp. 55, 1964.

6. Fellers, D. A., Sinkey, V., Shepherd, A. D., and Pence, J. W. Solubilization and recovery of protein from wheat millfeeds. Cereal Chem. 43:1, 1966.

7. Carpenter, K. J. and Clegg, K. M. The metabolizable energy of poultry feeding stuffs in relation to their chemical composition. J. Sci. Fd. Agric. 7:45, 1956.

8. Millfeed Manual. Millers National Federation, Chicago, Illinois, 1972.

9. Mattil, K. F. The functional requirements of proteins for foods. J. Amer. Oil Chemists Soc. 48:477, 1971.

WET MILLING OF WHEAT AND OATS BY ALKALINE EXTRACTION

Y. Victor Wu, K. R. Sexson, and J. E. Cluskey
Northern Regional Research Laboratory, Agricultural Research Service
United States Department of Agriculture

Market potential for functional protein approximates 3.1 billion pounds annually (1). The increasingly high cost of animal protein suggests a bright future for plant proteins. High-protein wheat and oats are currently being developed, and some varieties are already available. Alkaline extraction of wheat and oat groat proteins gives better yields than extraction at acidic pH and permits recovery of some water-soluble proteins. Since whole wheat and oat groats have higher protein contents and better amino acid composition than wheat and oat flours, we investigated wet milling of both high-protein wheat and oat groats by alkaline extraction.

Anderson et al. (2,3) used wheat flour in a batter process to separate gluten from starch. Slotter and Langford (4) reported a sulfurous acid process to separate gluten from whole wheat. In these processes, water solubles are generally lost. Although a number of alkaline-extraction procedures yield protein and starch from wheat flours (5-8), oat flour (5), and wheat millfeeds (8-10), none of these methods were ever applied to whole wheat grain or to oat groats.

Wheat and Oats. NE 701136 wheat, a gift from Dr. V. A. Johnson, Agricultural Research Service, U.S. Department of Agriculture, Lincoln, Nebraska, is a high-protein wheat with a protein content of 17.4% (N X 5.7, dry basis). The wheat was classified as a hard red winter wheat of acceptable bread baking quality. It was ground in a hammer mill.

Wyndmere oats had a protein content of 12.9% and Garland oats 15.7% protein (N X 5.7, dry basis). They were purchased from Interstate Seed and Grain Co., Fargo, N. D. The oats were dehulled in an Alpine pin mill and the resulting groats ground in a hammer mill. The yield of groats from whole oats is about 70%.

Wet Milling. Figures 1 and 2 give flow diagrams for wet milling ground wheat and ground oat groats, respectively; yield and protein content of products are also given. Yield of protein concentrate was greatest from oat groats but wheat yielded more starch. The starch recovered from oats had a low protein content.

The values given in Figure 2 are the averages for Wyndmere and Garland groats; there were processing differences however. High protein (21%, dry basis) Garland groats gave a 21% yield of protein concentrate with a protein content of 64% while lower protein (17%) Wyndmere groats gave the same yield of protein concentrate but with a protein content of only 54%. In work comparing two varieties of wheat, the higher protein content wheat yielded more protein concentrate and of a higher protein content. It appears there is a decided advantage to starting with high protein grain if high yield of protein concentrate of high protein content is desired. In the case of oats where fat content is relatively high, protein content of oat protein concentrate can be increased substantially by defatting or starting with defatted oat groats in the wet milling process.

The only previous wet-milling process on whole wheat grain was reported by Slotter and Langford (4). The sulfurous acid they used denatured the gluten during a 24-hour steep. The gluten had a protein content of 26 to 37% and represented 49 to 55% of the total wheat protein. Our procedure resulted in a protein concentrate with a protein content of 64% (Figure 1) and represented a recovery of 64% of the total wheat protein.

Composition of Protein Concentrate. Fat, fiber, and ash contents were determined by AACC Approved Methods (11). The wheat concentrate is low in fat (0.9%), but oat concentrate has 8.8% fat. Fiber content for both concentrates is very low (0.1 to 0.2%). The ash content of wheat concentrate is 1.2% while that of oat concentrate is 2.9.

Amino acid analyses were carried out by the method of Cavins and Friedman (12) on wheat and oat protein concentrates hydrolyzed for 24 hours in refluxing constant-boiling hydrochloric acid. Results are given in Table 1, as well as the amino acid pattern for human requirement as recommended by the Food and Agricultural Organization of the United Nations (13). The lysine content of 2.3 g/16 g. N for wheat protein concentrate is considerably below the FAO pattern of 4.2. This low lysine value in wheat concentrate is not surprising because wheat is known to be deficient in lysine. All other amino acids of wheat concentrate in Table 1, except isoleucine, essentially meet the human requirement. Oat protein concentrate has good amino acid composition meeting or exceeding the FAO pattern within experimental uncertainty.

Functional Properties of Protein Concentrates. The solubility of protein concentrate was determined by mixing 0.1 g. of concentrate with 10 ml. of water and adjusting to the desired pH with either hydrocholoric acid or sodium hydroxide solution. The mixture was stirred and centrifuged, and fractions of the centrifuged solution were analyzed for nitrogen.

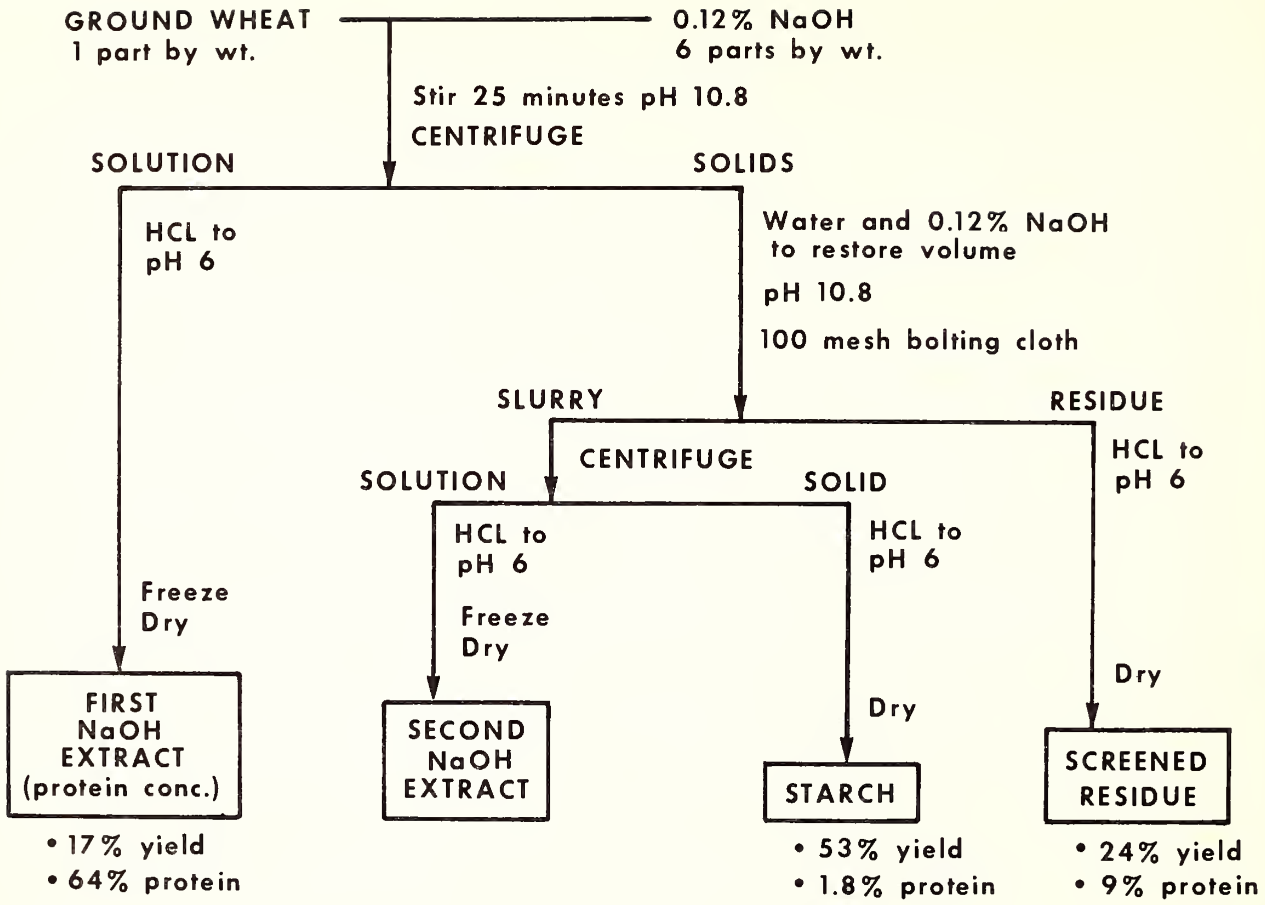


Figure 1. Wet milling ground wheat (17.4% protein N X 5.7); yield and protein values on dry basis.

Table 1. Amino acid composition of protein concentrates (g./16 g. nitrogen)

Amino Acid	Wheat	Oat[1]	FAO Pattern (13)
Lysine	2.3	4.0	4.2
Threonine	2.8	3.4	2.8
Total sulfur acids	2.9	3.8	3.0-3.5
Valine	4.2	5.5	4.2
Isoleucine	3.4	4.0	4.2
Leucine	6.6	7.9	4.8
Total aromatic acids	8.2	9.7	5.6

[1] Average of Garland and Wyndmere varieties.

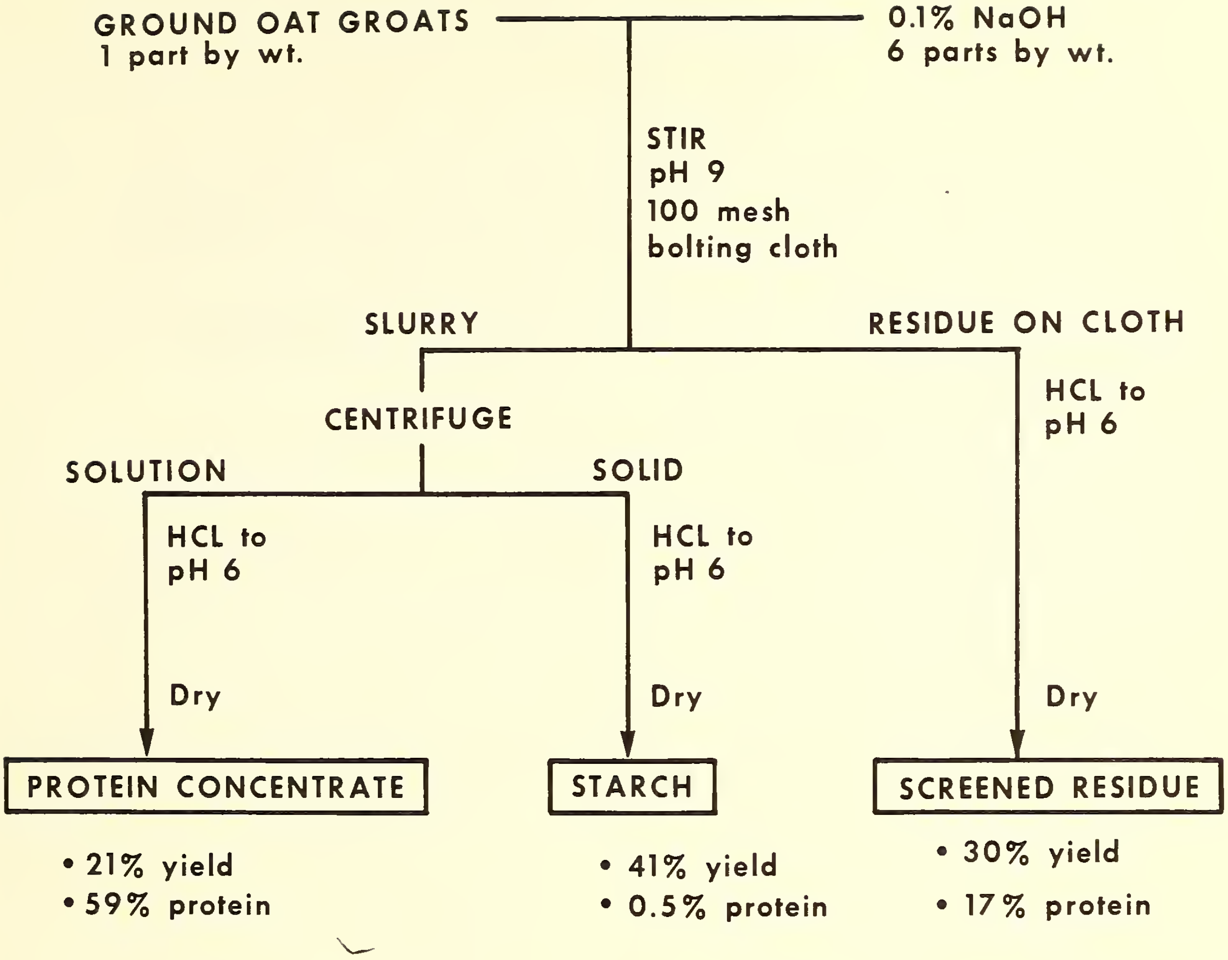


Figure 2. Wet milling ground oat groats (19.2% average protein content of Wyndmere and Garland groats, N X 5.7); all yield and protein values on dry basis.

The nitrogen solubility characteristics of wheat and oat protein concentrates differ. The solubility curve of wheat concentrate has a minimum of 23% at pH 6.1 and a maximum of 94% at pH 2.5; oat concentrate has a maximum nitrogen solubility of 83% at pH 2 and minimum solubility of 15% at pH 5.

Since wheat gluten is used in baked goods, it is of interest to evaluate the potential of wheat protein concentrate for that purpose. A commercial vital gluten, wheat protein concentrate, and a commercial devitalized gluten were compared in their abilities to form gluten balls. Each of the three solids was mixed with 1.5 parts of 0.1% NaCl solution. The vital gluten formed a strong and elastic gluten ball. The wheat concentrate formed a reasonably strong and elastic gluten ball but not quite as strong as that from vital gluten. The devitalized gluten could not form a gluten ball. Since the wheat concentrate contains gluten and water-soluble proteins and is lower in protein content than vital gluten, it is not surprising that the gluten ball from vital gluten is stronger.

Potential Uses of Protein Concentrates. Both wheat and oat protein concentrates may find application in conventional wheat foods to improve level and quality of protein in the final product. Other possible uses of these protein concentrates include meat extenders for substitutes and protein fortification of beverages. Wheat and oat screened residues could find uses in food with a high fiber content. Wheat starch already has accepted food and industrial outlets. Continued research will be necessary to optimize the wet-milling process and to evaluate the products from it for different food applications.

Literature Cited

1. Hammonds, T. M., and Call, D. L. Protein use patterns--current and future. Chem. Technol. 156, 1972.

2. Anderson, R. A., Pfeifer, V. F., and Lancaster, E. B. Continuous batter process for separating gluten from wheat flour. Cereal Chem. 35:449, 1958.

3. Anderson, R. A., Pfeifer, V. F., Lancaster, E. B., Vojnovich, C., and Griffin, E. L., Jr. Pilot-plant studies on the continuous batter process to recover gluten from wheat flour. Cereal Chem. 37:180, 1960.

4. Slotter, R. L., and Langford, C. T. Wheat starch manufacture, a new method. Ind. Eng. Chem. 36:404, 1944.

5. Dimler, R. J., Davis, H. A., Rist, C. E., and Hilbert, G. E. Production of starch from wheat and other cereal flours. Cereal Chem. 21:430, 1944.

6. Fellers, D. A., Johnston, P. H., Smith, S., Mossman, A. P., and Shepherd, A. D. Process for protein-starch separation in wheat flour. Food Technol. 23:162, 1969.

7. Johnston, P. H., and Fellers, D. A. Process for protein-starch separation in wheat flour. 2. Experiments with a continuous decanter-type centrifuge. J. Food Sci. 36:649, 1971.

8. Phillips, K. L., and Sallans, H. R. Ammonia process for separating starch and gluten from wheat flour. Cereal Sci. Today 11:61, 1966.

9. Fellers, D. A., Sinkey, V., Shepherd, A. D., and Pence, J. W. Solubilization and recovery of protein from wheat millfeeds. Cereal Chem. 43:1, 1966.

10. Saunders, R. M., Conner, M. A., Edwards, R. H., and Kohler, G. O. Protein concentrates by wet processing of wheat millfeeds. Abstr. Paper 66, 57th Annual Meeting of the American Association of Cereal Chemists, October 1972, at Miami Beach, Florida.

11. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. AACC Approved Methods (revised). The Association, St. Paul, Minnesota. 1971.

12. Cavins, J. F., and Friedman, M. Automatic integration and computation of amino acid analyses. Cereal Chem. 45:172, 1968.

13. FAO/WHO. Protein requirements. Report of a joint FAO/WHO Expert Group. Food and Agricultural Organization of the United Nations, FAO Nutrition Meeting Report Series 37, p. 36, Rome. 1965.

NONAQUEOUS PROTEIN-STARCH SEPARATION

J. W. Finley and E. Hautala
Western Regional Research Center, Agricultural Research Service,
United States Department of Agriculture

Improved techniques of wheat protein-starch separation has been a challenge of long standing. In early days, the cosmetic properties of starch made it a highly sought after commodity. More recently, the unique functional properties of gluten have been more widely recognized and interest in its recovery and use has been growing. Fellers (1) and Anderson (2) have reviewed the processes for recovering wheat proteins by aqueous methods; they all entail water pollution problems to one degree or another. Ideally, a nonaqueous process will avoid water pollution; additionally, substantial energy savings might accrue, especially in drying operations if a solvent of low specific heat can be used.

A nonaqueous system for wheat protein-starch separation can be approached in two ways: 1. Solubilization of either the protein or starch by the solvent, or 2. A physical separation based on density differences. In this work, the density separation was employed.

Hess (3) has reported the separation by density of interstitial protein of endosperm using a mixture of benzene and carbon tetrachloride. Stevens (4) employed the same technique on air classified material to recover protein for chemical characterization. Barlow (5) has also reported work on protein recovery by density separation.

For the nonaqueous separation of food protein, the solvent must be in the correct density range, be nontoxic and have a low boiling temperature and heat of vaporization for economical and complete solvent recovery. Carbon tetrachloride and benzene do not meet these criteria.

Table 1 shows the effect of moisture content on the apparent densities of protein and starch.

Table 1. Effect of moisture on density of wheat protein and starch (calculated from data presented by Hess (3)).

Moisture	Density Protein	 Starch	 Difference
0	1.345	1.500	0.155
4	1.331	1.480	0.149
8	1.317	1.460	0.143
12	1.303	1.440	0.137
16	1.290	1.420	0.130

As the moisture content increases, the densities of both protein and starch decrease linearly. For the density separation to be effective, the solvent density must be between that of the protein and starch.

The desired solvent density for working with a 12% moisture flour would be between 1.44 and 1.303 (Table 1). This narrow range limits the availability of suitable solvents. The fluorinated hydrocarbons offer some of the desired properties and small adjustments downward in density can be made by addition of hexane, ethanol or an ester such as ethyl acetate. Table 2 gives physical properties of several of the fluorinated hydrocarbons. With density adjustment, all of these solvents could be used.

Table 2. Physical properties of fluorinated hydrocarbons (6)

DuPont Name	Chemical Formula	Density as Liquid at 25°C	Boiling Point °C	Heat of Vaporization cal/gm
Freon 11	CCl_3F	1.476	23.82	43.10
Freon 12	CCl_2F_2	1.311	-29.79	39.47
Freon 113	$CCl_2F\text{-}CClF_2$	1.565	47.57	35.07
Freon 114	$CClF_2\text{-}CClF_2$	1.456	5.77	32.51
Freon C318	$c\text{-}C_4F_8$	1.500	-5.85	27.77

Freon 12 offers excellent properties except for its very low boiling point. The most ideal solvent, based on physical properties is Freon 114. However, work reported here has been carried out with Freon 11 (CCl_3F); its higher boiling point was of great convenience when working in the laboratory at room temperature and with non-pressurized apparatus.

The relationship between hexane:Freon 11 mixtures and density for two temperatures is shown in Figure 1. The change in density with temperature points out that precise temperature control is critical to success in the nonaqueous protein-starch separation process.

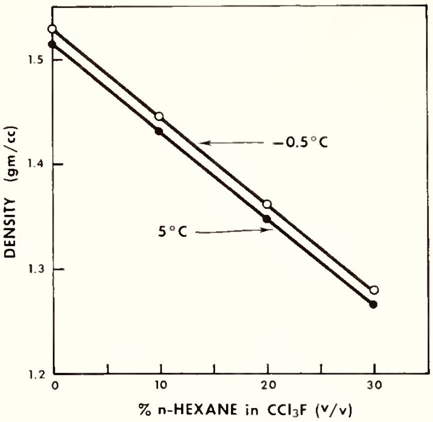


Figure 1. Densities of hexane:CCl_3F mixtures at two temperatures.

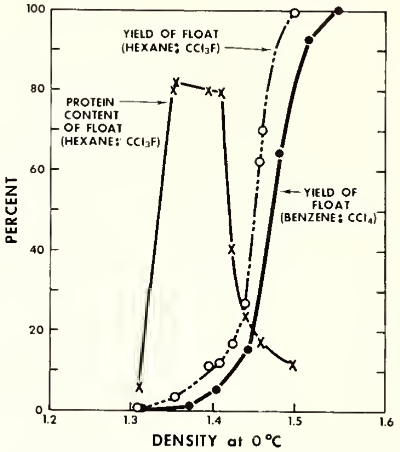


Figure 2. Effect of solvent and solvent density on percent of flour floating and on protein content (dry basis) of the floating material.

Flour Fractionation; Laboratory. One gram portions of ball milled HRW flour at 10.1 percent moisture were suspended in 100 milliliters of hexane: CCl_3F mixtures or benzene: carbon tetrachloride mixtures at 0°C and mixed for 30 seconds with a DuMore shear type blender. The samples were centrifuged at 0°C in a Sorvall refrigerated centrifuge for 10 minutes at 5000 rpm. Results are shown in Figure 2. As expected with both solvent systems, the floating material increases with increasing density particularly above 1.43 with the hexane:CCl_3F and above 1.45 with the benzene:CCl_4 solvent system. The difference is apparently a specific solvent effect. The protein content of the floating material reached a plateau value of about 80% when the float yield was between 3 and 12%. At 12% float yield, the protein content of the starch pellet was minimum.

Next, the effects of various flour treatments on the separation at a single density were evaluated. Table 3 shows the effects of ball milling, turbomilling, and the addition of acetic acid or sodium hypochlorite to the solvent to be used in the processing. Ball milling significantly improved separation

Table 3. Protein recoveries when the density separation process was used on HRW flour treated in various ways

Flour Treatment[1]	% of Flour Solids in:		Protein Content, % db.		% of Total Flour Protein in
	Float	Sink	Float	Sink	Float
Control	13.56	85.44	73.0	2.58	81.8
Ball Milled	11.04	88.96	93.6	1.98	85.4
Turbomilled	12.07	87.93	85.3	2.05	85.1
Turbomilled and 1% Acetic Acid[2]	12.20	87.80	84.7	2.01	85.4
Turbomilled and 1% NaClO[3]	12.51	87.49	92.7	0.46	95.8

[1] All flours processed were at 10.1% moisture. Protein content was 12.1% dry basis. The flour: solvent ratio was 1:100 (w/v). The solvent was hexane: CCl_3F 14:86 (v/v) with a density of 1.415 at 0°C.

[2] 1 ml of 5% aqueous acetic acid to 99 ml of solvent.

[3] 1 ml of 5% aqueous sodium hypochlorite to 99 ml of solvent.

while the best results were obtained with turbomilled flour processed with solvent containing sodium hypochlorite. The purpose of the acetic acid and sodium hypochlorite was to assist the rupture of the protein-starch interaction thereby improving the separation. While the sodium hypochlorite was somewhat successful in this role, the acetic acid was not.

Scale-Up. Figure 3 shows a schematic diagram of a small pilot unit for density separation of protein from flour. Also included in the figure are the results of a run using the equipment.

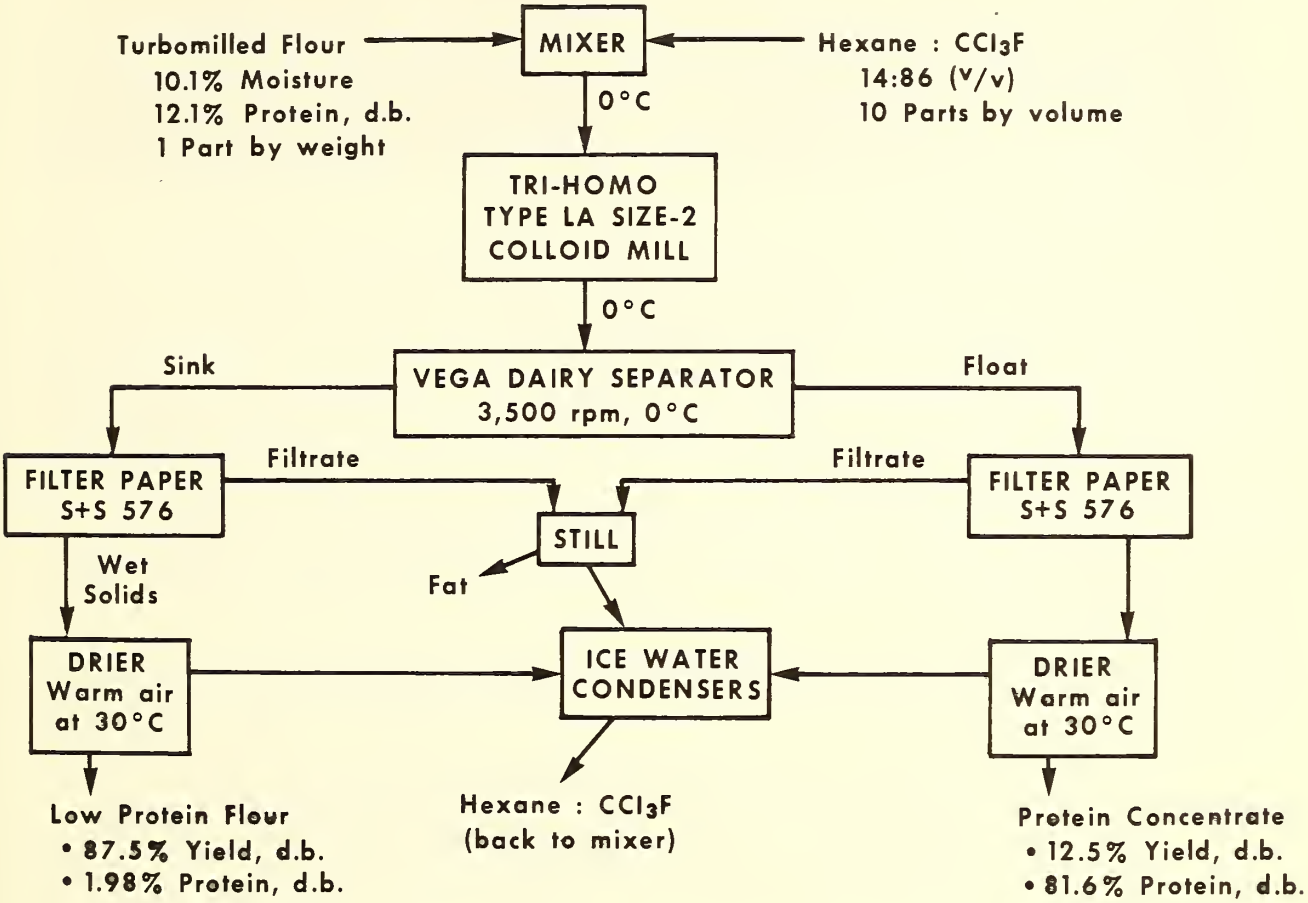


Figure 3. Schematic of small pilot unit for density separation of protein from wheat flour.

Of the total protein in the starting wheat flour, 84.3 percent was recovered in the floating protein concentrate. Of note here is the 1:10 flour:solvent ratio (w/v) used compared with the 1:100 ratio in the laboratory experiments.

Evaluation of the Protein. Protein concentrate before drying was recombined with low protein flour and the process solvent (containing lipids) and the total mixture evaporated to dryness. Farinographs were run on the reconstituted flour and are compared to unprocessed flour in Figure 4. Absorption increased from 57.2 percent to 60.2 percent which was probably due to starch damage sustained in the colloid mill. Pup loaves showed volumes of 690 cc and 735 cc respectively for control flour versus reconstituted. Hexane:CCl_3F processing of the flour did not adversely affect baking quality.

Separation of Protein in Soy, Peas and Whey. One gram of each protein source was slurried in 100 milliliters of hexane:CCl_3F 14:86 (v/v) solvent at a density of 1.415, sheared and centrifuged. The results are shown in Table 4 and are evidence of the applicability of the density separation system on other materials as well as wheat flour. The solvent extracts lipid materials and any continuous, solvent recycling process will require a method for defatting the solvent. In some instances, the fat might be induced to crystallize out at lower temperatures.

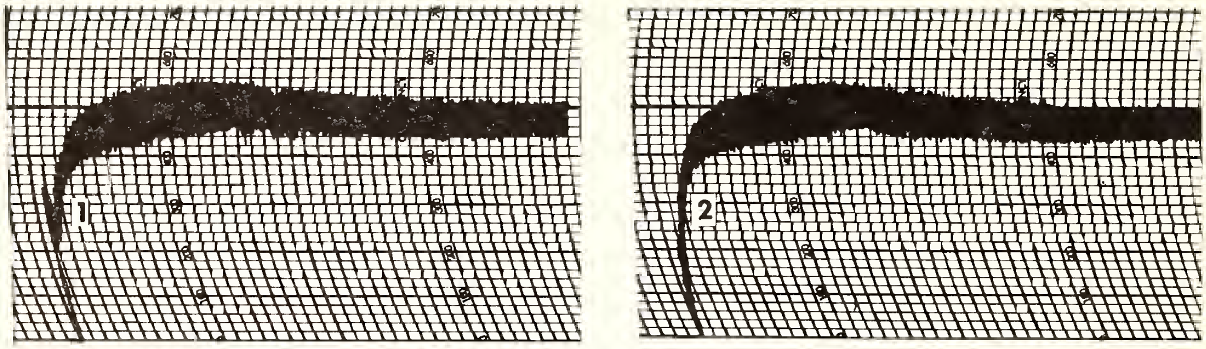


Figure 4. Farinographs of control flour (1) versus solvent fractionated and reconstituted flour (2).

Table 4. Recovery of protein concentrates from soy, peas and whey by density separation in hexane: CCl_3F 14:86 at 0°C. Product:solvent ratio was 1:100 w/v

Protein Source	Protein Content, of float, %, db.	% of Total Protein recovered in float
Whole ballmilled soy	59.8 (80.1)[1]	83.0
Full fat soy flour	87.2	84.1
Dry split peas	63.1	80.7
Whey	93.6	78.5

[1] After removal of hull fragments (reslurry in CCl_3F and screen on an 80 mesh sieve).

Conclusions. Laboratory and small pilot unit experiments have demonstrated a technical feasibility for density separation in hexane: CCl_3F mixtures of protein in wheat flour, soy, peas and whey. Baking of the recombined components of wheat flour points out that the separation can be achieved without damage to functional properties of the protein. Potential advantages of density separation processes are reduced energy requirements, elimination of water pollution problems, and retention of native protein functional properties by elimination of heat damage, a prevalent problem in drying protein concentrates obtained from conventional wet processes.

Literature Cited

1. Fellers, D. A. Fractionation of wheat into major components. In: Industrial Uses of Cereals. Ed. Y. Pomeranz, Am. Assoc. of Cereal Chemists, St. Paul, Minnesota, 1973.

2. Anderson, R. A. Manufacture of Wheat Starch. In: Starch Chemistry and Technology; Vol. II. Industrial Aspects. Ed. R. L. Whistler and E. F. Paschall. Academic Press, New York, 1967.

3. Hess, K. Protein, Kleber und Lipoid in Weizenkorn und Mehl. Kolloid Zeitschrift 136:84, 1954.

4. Stevens, D. J., E. McDermott and J. Pace. Isolation of endosperm protein and aleurone cell contents from wheat and determination of their amino acid composition. J. Sci. Fd. Agric. 14:284, 1963.

5. Barlow, K. K., M. S. Buttrose, D. H. Simmons and M. Vesk. The nature of the starch-protein interface in wheat endosperm. Cereal Chem. 50:443-454, 1973.

6. Anon. Freon Fluorocarbons. Properties and Applications. E. I. DuPont Nemours and Co., Wilimington, Delaware, 1969.

EFFECT OF STEAM CONDITIONING AND HEAT TREATMENT ON DURUM WHEAT MILLING

A. Seyam and D. E. Walsh
Department of Cereal Chemistry and Technology, North Dakota State University
and
W. C. Shuey and R. D. Maneval
North Central Region, Agricultural Research Service, U.S. Department of Agriculture

The main objective of wheat conditioning is to bring wheat into the best physical condition for milling. Proper wheat conditioning will cause a desirable moisture differential throughout the wheat kernel with more moisture in the bran and will improve the separation of endosperm from the bran. Conditioning of durum wheat has an important role since large chunks of endosperm (semolina) must be produced with complete absence of bran and other specks. Wheat conditioning may be done by cold or warm process. The warm process may be accomplished by either heat or steam or both. The steam can be applied directly or indirectly. Time is another very important factor in the different methods of wheat conditioning.

Durum wheat conditioning is usually different from bread wheats since more moisture is desirable in the bran than in the endosperm to obtain semolina free of specks.

Several investigators have looked at the effect of conditioning on wheats other than durum (1-9). Nelstrop (10) recently reported that conditioning of durum is dependent on quality of durum and color of pasta products desired. A low grade durum will have faster moisture penetration and will give semolina with more flour, while the top grade durum will condition satisfactorily, and the longer the conditioning time the lighter the color of the product. He also reported that it is best to have three stages of moisture addition to obtain the best moisture differential. The third addition is mainly to toughen the bran just before milling.

Most investigators have discussed quality of pasta products as related to varieties, granulation, and processing methods (11-18), but few have considered the influence of wheat treatment. Irvine _et al._ (19) demonstrated an improvement in semolina quality when steam treatment was used. This study was conducted to determine what influence wheat treatment has on durum milling and pasta processing.

MATERIALS AND METHODS

Wheat Sample. A blend of durum wheats from the 1971 crop was used for the purpose of this study. Physical factors were determined as described by Shuey (20). Table 1 gives physical and chemical data of the durum wheat mix.

Table 1. Physical and chemical data of the durum wheat mix

Test weight	62.7 lb./bushel		
Vitreous kernels	89.0%		
1000 Kernel weight	36.8 g.		
Protein, 14% moisture basis	13.0%		
Moisture	12.5%		
Kernel distribution	_Large_	_Medium_	_Small_
	39%	60%	1%

The sample was cleaned by passing the wheat over an Emerson kicker and dockage tester and through a modified Forster scourer Model 6. The clean dry sample was pretempered to 12.5% moisture for at least 72 hr. prior to any additional tempering.

Milling Flow. The samples were milled on a Buhler experimental mill, specially designed for milling durum wheat and equipped with corrugated rolls throughout. The semolina was purified on a Miag laboratory purifier. All of the stock was handled pneumatically. A flow diagram of the mill is shown in Figure 1 (coarse flow).

Different particle size distribution was accomplished by changing the sieves on the break scalps, reduction scalps, conveyer tube, and position #4 on purifier #1. The very fine particle size was obtained by passing coarse semolina obtained from the coarse grind through the reduction section of the regular Buhler mill.

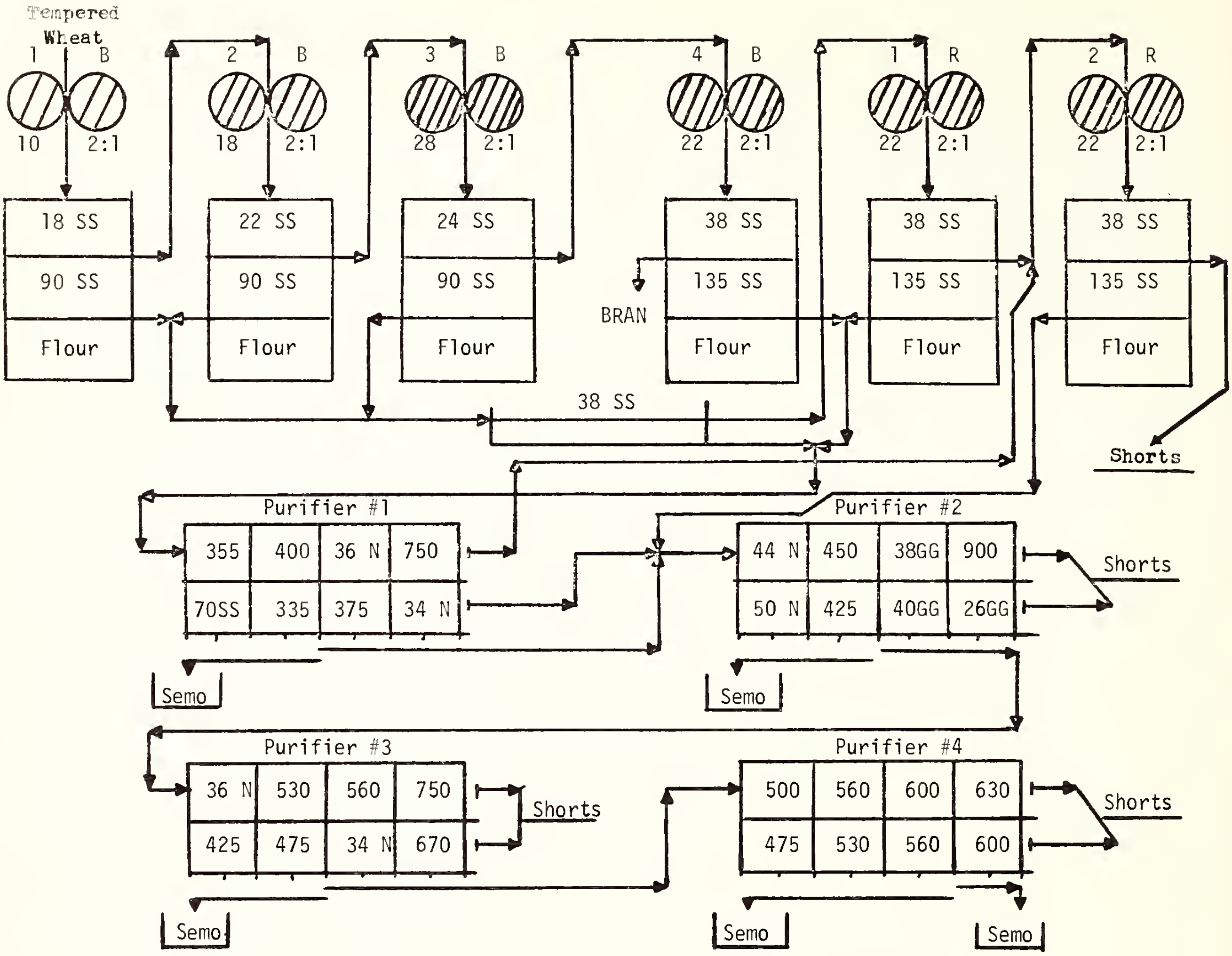


Figure 1. Milling flow diagram for large durum wheat samples.

Wheat Treatments.

a) Regular tempering. The dry wheat was tempered in three stages: first to 12.5% moisture at least 72 hr. prior to the second stage which adds an additional 2.0% for 18 hr. to give a cumulative moisture of 14.5%, then a final temper of 3.0%, 45 min. prior to milling.

b) Steam treatment. Samples previously tempered to 12.5% moisture were treated with steam for 30 seconds on position #3 of the regulating valve in the steam inlet pipe of the Miag laboratory conditioner. The samples had a rest period of 1/2 hr. after steaming before milling.

c) Tempering and heat treatment. Samples previously tempered to 12.5% moisture were given an additional 3.5% moisture to give a cumulative moisture content of 16%, then heated to 60°C. inside the Miag laboratory conditioner drum and held for 15 min. The total time elapsed was 1/2 hr. The heated wheat was milled immediately after removal from the drum.

d) Tempering and steam treatment. Samples pretempered to 12.5% moisture were given an additional 1% water to give a cumulative moisture content of 13.5%, then rested for 1/2 hr. before steaming for 20 seconds using a Miag laboratory conditioner. The samples then rested for 1/2 hr. prior to milling.

Semolina Quality. Protein and ash were determined by AACC Approved Methods (21) and all values are reported on a 14% moisture basis. Absorption in the water, expressed as percent of the semolina, required to bring the dough to proper consistency for processing. Absorptions are reported on a 14.0% moisture basis. Mixograms of semolina were obtained by using 25 g. of semolina and 12 ml. of water, on spring setting #7 of the mixograph.

Spaghetti Processing. Spaghetti was processed on a semi-commercial scale pasta extruder (Demaco). The control as well as the other samples were processed with the following extruding conditions: Temperature - 46.5°C., Rate - 20 r.p.m., Vacuum - 18 in. Hg. These were the optimum conditions for processing spaghetti which were calculated by the linear programming technique (18). One-half percent additional water was added to the fine and very fine granulated semolina for proper consistency.

Quality Measurements. The color of dry spaghetti was measured with a Hunter color difference meter (Model D 20), according to the method of Walsh *et al.* (22). The cooked weight and cooking loss of the spaghetti were measured according to AACC Approved Methods (21). Cooked spaghetti firmness was measured with an Instron universal test instrument equipped with the special shearing tooth described by Walsh (23). The amount of work (g. cm.) required to shear two cooked spaghetti strands was used as a measure of firmness.

RESULTS AND DISCUSSION

Semolina; Extraction Rate and Quality. The data in Table 2 show that durum wheat treated with steam for 30 sec. (treatment b) gave the best extraction on the average with minimal speck count compared to the other treatments, regardless of the flow. Also, the moisture content was 1% less than the regular procedure. The other two samples which had been heat treated or tempered and steamed showed marked improvement over the regular tempering procedure, but tended to be higher in speck count than the steam treated sample.

Table 2. Data on semolina milled from durum with different conditioning treatments and particle size

Granulation and Treatment[1]	Extraction[2] %	Ash[2] %	Protein[2] %	Absorption[2] %	Moist. %	Dust Color	Specks	Distribution[3] Over 40	Over 60	Over 80	Over 100	Thru 100
Coarse												
a	60.4	0.67	12.5	31.5	14.1	11.0	33	32.9	48.3	13.7	2.6	2.5
b	63.1	0.70	12.6	31.5	12.7	11.0	30	34.7	46.9	13.0	3.0	2.4
c	62.4	0.69	12.5	31.5	12.9	11.0	33	31.6	47.0	14.7	3.6	3.1
d	63.6	0.73	12.8	31.5	13.0	11.0	50	32.2	46.6	14.7	3.4	3.1
Fine[4]												
a	58.1	0.70	12.4	32.0	14.0	10.0	33	5.3	59.9	22.7	5.9	6.4
b	62.1	0.72	12.4	32.0	13.0	10.0	43	5.0	59.7	23.0	5.5	6.8
c	60.6	0.72	12.6	32.0	13.2	10.5	50	5.0	59.5	24.1	5.9	5.5
d	60.9	0.71	12.7	32.0	13.0	10.0	40	4.3	60.5	23.2	6.3	5.7

[1] a = regular tempered, b = steam for 30 sec., c = tempered and heated, d = tempered and steam for 20 sec.

[2] 14% moisture basis.

[3] The percent extraction of fine flow was adjusted to the same percent extraction of the coarse flow when processing the semolina by adding 2nd and 3rd break flour to the semolina. The particle size distribution was determined on the semolina after adding the flour.

[4] The percent extraction given for the fine semolina is the unadjusted extraction.

Semolina color for the coarse flow was higher than those of the fine flow due to particle size. No noticeable effect on particle size distribution or other chemical or physical properties of the semolina was observed due to different treatments for a given flow as shown by the exemplary data in Table 2.

Durum wheat treated with steam for a period of 60 sec. or more gave lower percent extraction (Table 3). Also, the semolina milled from wheat with longer steam treatment had lower color score due to an apparent destruction of the pigment by steam.

Table 3. Effect of steam time on milling performance of durum

Steam time[1]	% Extraction	Dust Color	Specks
20 sec.	65.8	11.0	77
30 sec. (treatment b)	63.1	11.0	30
40 sec.	62.1	10.0	33
60 sec.	55.9	9.0	30

[1] Durum adjusted to 12.5% moisture at least 72 hr. prior to steaming.

The mixograms for all the treated samples showed no difference in their pattern. The mixograph absorptions for the very fine semolina was increased by 8% over the other samples. This increase in the water absorption for the fine and very fine semolina is apparently due to the damaged starch.

Spaghetti Quality. Differences in cooked weight, cooking loss, and firmness of spaghetti between samples were not significant. This would indicate that the quality of the final product could be maintained by any of the treatments as shown by data in Table 4.

Table 4. Effect of heat treatment on pasta quality.

Granulation and Treatment[1]	Color Score	Cooked Weight	Cooking Loss, %	Firmness g. cm.
Coarse				
a	8.5	35.7	5.0	4.24
b	8.5	35.6	7.0	4.67
c	9.0	36.1	6.0	4.43
d	9.0	35.2	6.0	4.48
Fine				
a	8.5	37.7	6.0	3.68
b	8.5	35.8	5.0	4.62
c	8.5	37.1	6.0	3.80
d	8.5	36.6	8.0	4.14

[1] See footnote 1, Table 2.

Conclusions. Heat treatments of durum wheat increased the milling performance without noticeable effect on quality of produced semolina or pasta products compared to the regular cold method. A short conditioning process is feasible when live steam is used and gives the best results.

Granulation did not appear to influence the final quality of the pasta product within the range studied.

ACKNOWLEDGMENTS

The authors wish to thank M. H. Boeder and Slavko Vasiljevic for their assistance in processing the samples, and Cargill, Inc., Minneapolis, MN, for for financial support.

Literature Cited

1. Anderson, J. E. What water does to wheat in tempering. A.O.M. Bul. p. 794, May 1937.

2. Bradbury, Dorothy, Hubbard, J. E., MacMasters, Majel M., and Senti, F. R. Conditioning wheat for milling. A survey of literature, Agricultural Research Service, U.S. Department of Agriculture. Misc. Publication No. 842, May 1960.

3. Eustace, W. D., and Farrell, E. P. Warm, cold, and cold-soak methods to condition wheat. A.O.M. Bul. p. 2722, May 1963.

4. Kent-Jones, D. W., and Amos, A. J. Modern cereal chemistry (6th edition), Food Trade Press, Ltd., 1967.

5. Lockwood, Sir Joseph. Flour milling (4th edition). Northern Pub. Co., Liverpool, 1960.

6. Momtaz El-Gindy, M., and Schaefer, W. Some microscopic changes in the aleurone layer of wheat during conditioning. Cereal Sci. Today 3: 61, 1958.

7. Seeborg, E. F., and Barmore, M. A. The influence of milling moisture on flour yield, flour ash, and milling behavior of wheat. Northwest. Miller, Milling Prod. 17(7): 1, 1952; 248(2): 1a, July 8, 1952.

8. Sugden, G. H. Various aspects of wheat conditioning. Cereal Sci. Today 1: 136, 1956.

9. Ziegler, E., and Greer, E. N. Principles of milling. In: Wheat Chemistry and Technology, 2nd ed., AACC Monograph Series, Vol. III p. 115, 1971.

10. Nelstrop, P. C. A closer look at semolina milling. Milling 11: 16, November 1972.

11. Black, H. C., and Bushuk, W. Modification of the Buhler laboratory mill for milling semolina. Cereal Sci. Today 12: 164, 1967.

12. Black, H. C. Laboratory purifier for durum semolina. Cereal Sci. Today 11: 533, 1966.

13. Fabriani, G. Principles of evaluation of durum wheats and their products. Cereal Sci. Today 11: 339, 1966.

14. Harris, R. H., Sibbitt, L. D., and Scott, G. M. The particles size of semolina in relation to quality. Food Technology 9: 449, 1955.

15. Irvine, G. N. Durum wheat. Cereal Sci. Today 10: 328, 1965.

16. McGee, B. New techniques in semolina milling. Milling & Baking News p. 8, May 1973.

17. Sollberger, H. Lab grinding test for durum semolina. Northwest. Miller 277: 8, October 1970.

18. Walsh, D. E., Ebeling, K. A., and Dick, J. W. A linear programming approach to spaghetti processing. Cereal Sci. Today 16: 385, 1971.

19. Irvine, G. N., Bradley, J. W., and Black, H. C. Improvement of semolina quality through steam treatment of durum wheat. Cereal Chem. 44: 230, 1967.

20. Shuey, W. C. Durum wheat quality report. Agricultural Research Service, U.S. Department of Agriculture and Dept. of Cereal Chem. & Technology, N. Dak. State University. 1972.

21. American Association of Cereal Chemists. AACC Approved methods. The Association: St. Paul, Minn. 1962.

22. Walsh, D. E., Gilles, K. A., and Shuey, W. C. Color determination of spaghetti by the tristimulus method. Cereal Chem. 46: 7, 1969.

23. Walsh, D. E. Measuring spaghetti firmness. Cereal Sci. Today 16: 202, 1971.

AGRICULTURE AND INDUSTRIAL ENERGY

Dwight L. Miller, Assistant Area Director
Northern Regional Research Laboratory, Agricultural Research Service
U.S. Department of Agriculture

Agricultural products are a major renewable source of energy. Agriculture has normally been included in the energy-producing sector of the U.S. economy. However, overall, the production, processing and distribution of agricultural crops consumes more energy than it provides. Power, from machines, with major inputs from fossil fuels, has resulted in greatly increased production. Agriculture based primarily on human-animal power cannot provide the food and fiber for the United States. Maximum utilization of total materials, including byproducts and residues, is a future necessity to reduce the energy imbalance.

The United States enjoys the highest standard of living of practically any country in the world. Most Americans want nothing less. Low-cost and plentiful raw materials have been basic to our nation's growth and prosperity. The rate at which our consumption of energy is increasing closely parallels the rate of increase in our gross national product. Any major move to restrict the growth and use of energy is bound to have an adverse effect on the U.S. economy and on our way of life.

The United States is rapidly developing a shortage of low-cost energy raw materials and thus may be on the verge of losing one of its most important fundamental advantages. We are all concerned with how this could affect agriculture.

Agriculture has normally been included in the energy-producing sector of our economy. Agricultural products are now the major renewable energy source. Plants are converters of solar energy into usable and storable forms of products. However, on an average, plants utilize less than 1 percent of the available solar energy that hits them. Cereal grains, and in fact most agricultural materials, have primarily supplied our food and fiber in the United States. With the exception of wood, they have been little used as an industrial energy raw material.

American agriculture and its advancement, like all other industries, have been dependent upon an abundance of low-cost energy. The utilization of fossil fuels has been the major reason for the rapid increase in agricultural productivity in the 20th century. Man's muscle power is rated at only 1/20 h.p. continuously. On this basis, it would take at least 2,000 men just to power a small automobile. Each jet aircraft pilot controls the energy equivalent to about a million men. Some of the overall relations and dependency of agriculture and energy fuels will be reviewed in this discussion.

As late as 1920, about 25 million horsepower of energy was provided by animals and these animals required about one-fourth of the harvested crop acreage to feed them. Today, U.S. farmers would require up to fifty times more cropland than now used just for feeding, if they were to get their farm horsepower from horses and other animals. This much land would just not be available so the total production would not be possible. The use of tractors and other machines, powered directly or indirectly by fossil fuels, has also freed most of the cultivable land to produce foods for humans, and has also freed human labor for other uses. One man plowing with a tractor can do the work of several men plowing with horses. We are proud that, on an average, one farmer in the United States now provides food and fiber for approximately 51 people (42 at home, 9 abroad) as compared to only 16 people as late as 1950.

There are approximately 2,266 million acres in the 50 U.S. states. The land in farms is about 1,110 million acres, of which there are potentially about 630 million acres that could be cultivated. Normally, 300 to 360 million acres have been planted with cultivated crops, primarily cereal grains. Cereal grain production per acre for the past decade has varied, but has exceeded the growth rate of the United States population and export demands.

The replacement of human energy by mechanical power is shown in Table 1 (1). Mechanical power permitted one man to farm a large area and, with a relatively constant low fuel price, his expenses

Table 1. Production of United States crops--Labor versus mechanical power

Year	Tractor Horsepower millions	Labor Farm Work, Hours millions
1920	5	13,406
1950	93	6,922
1960	153	4,590
1970	203	3,209
1972	209	3,170

increased only marginally when he increased his acreage. Mechanization of agriculture also created a requirement for large amounts of nonfarm inputs in agriculture. The manufacture of tractors, trucks, and processing machinery and the production of fertilizers and the many other materials for agriculture have become some of our major industries. American agricultural-support industries are estimated to employ annually around 2 million man-years.

Certainly a return to complete man and animal agricultural operations is no longer possible. The food and fiber for our present population could not be provided by such operations and certainly none would be available for export. The world effects would indeed be tragic. Such action cannot even be considered.

The energy equivalent of an average acre of corn is given in Table 2 (2). Energy may come from the grain itself, as well as from the large amount of stalks, cobs and hulls produced simultaneously. The energy equivalent from the 100 bushels of grain (average) is about 38 million BTU's. The residues (stalks, cobs) from this acre, could yield in the order of 50 million additional BTU's for a total of about 88 million BTU's.

Table 2. Corn—Production of industrial energy. (Basis: One acre-100 bushels at 14.0% moisture)

Corn	Million BTU
Grain	
Whole grain, heat equivalent	38.5
Convert to alcohol,[1/] heat equivalent	19.0
Stalks, Cobs, Husks	
Heat equivalent (average)	50.0

[1/] Plus 1,930 pounds of byproduct grain.

Similarly the energy equivalent of an average acre of wheat is given in Table 3 (3).

Table 3. Wheat--Production of industrial energy. (Basis: One acre - 30 bushels at 13.5% moisture)

Wheat	Million BTU
Grain	
Whole grain - heat equivalent	12.5
Convert to alcohol,[1/] heat equivalent	6.1
Straw	
Heat equivalent	28.8

[1/] Plus 470 pounds of byproduct grain.

The grain is equivalent to about 12 million BTU's and the straw could yield about 30.0 million additional BTU's, or a total of about 42 million BTU's. Under present U.S. operations, the energy in the grain is about the only portion utilized and practically none of this is used for the production of industrial energy.

The present U.S. population annually consumes as food in the order of 1,000 trillion BTU's or about 4.5 million BTU's per person. Thus, each person theoretically would require the heat equivalent from the grain in about one-eighth of an acre of corn (100 bushels/acre) or one-third of an acre of wheat (30 bushels/acre).

In reality, the harvested acreage used to produce crops for domestic use was 1.01 per capita in 1972, down from 1.44 in 1960 and 1.94 in 1950. The production of our vegetables, fruits, sugar crops, cotton, tobacco and other noncereal materials also requires land. If the land used for pasturing and grazing is included, the per capita usage would more than triple.

If we related this basic food energy requirement to a gasoline basis, it amounts overall to about 35 gallons per person. In the United States, the on-the-farm consumption of fuel for farming is also equivalent to about 35 gallons of gasoline for every person and is increasing (4). Including the energy required to produce the fertilizer (N-P-P), which has increased 500 percent since 1950, and other farm chemicals; to manufacture the farm equipment; to process the products into safe and usable forms; to package and distribute the foods and to carry out the many other operations, directly or indirectly related to agriculture, the overall energy consumption ratio increases to over six times our direct consumption as foods and fibers. Some crops are lower and some are higher in energy consumption. The ratio of energy consumption versus energy content for cereal grains is estimated to be about four times.

Agriculture still is a minor user of industrial energy in the United States. The total 1972 U.S. industrial energy consumption was about 70,000 trillion BTU's equivalent annually to the energy in about 2,500 gallons of gasoline per person. The industrial energy demand is forecast to practically double by 1985. In comparison, agriculture consumption of about 200 gallons per person does not seem excessive. Besides, about 20 percent of our acreage is used to produce materials for export and for industrial purposes. However, as mentioned earlier, agriculture is supposed to be in the energy-producing sector, but, in reality, is a net consumer of energy.

Practically all energy raw materials must normally be processed or converted into usable forms, and major energy losses occur in this conversion. The maximum thermal efficiency attainable in present fossil fuel power plants is less than 50 percent, and the projected attainable goal is only about 60 percent. The petroleum industry consumes about 20 percent of the energy in the crude oil just to process and produce the fuel for our internal combustion engines. Then the overall fuel efficiency of this gasoline, when actually used in U.S. automobiles, is less than 25 percent.

The same conditions apply to agricultural products, including the cereal grains. Although the unit energy to produce cereal grains is much lower than to produce vegetables, fruits and many other agricultural crops, cereals must also practically always be processed in some way after they leave the farm and energy is required to do this.

The utilization of the byproducts for fuel or to replace materials that now require energy fuels to process must also receive consideration. As presented earlier, there is about twice as much energy in the cereal byproducts as in the grain. Sugarcane bagasse, the byproduct of sugar manufacture, has been commonly used as a boiler fuel in the sugar mills, and sugar production has one of the lowest energy consumption ratios. One ton of fuel oil is equivalent to about 6 tons of bagasse (50 percent moisture) for its heating value. It is also equivalent to about 4.5 tons of dry straw from wheat production or cornstalks from corn production.

A consideration of fuel possibilities from a basic fermentation industry is the production of ethyl alcohol. Cereal grains are not directly usable to our internal combustion engines. However, starch, the major portion of all cereal grains (60 to 70 percent), can be readily converted to ethyl alcohol by fermentation, and alcohol is an excellent motor fuel. About 2.6 gallons of anhydrous alcohol can be produced from a bushel of wheat. The heat equivalent of this alcohol is approximately 50 percent of the heat equivalent of the whole grain. The remainder is in the byproduct grains or is lost during the fermentation. Equally important is the energy required to produce the alcohol from the grain versus the energy in the final product. In general, this energy input ratio is about 1.5 to 1.0.

Every processing industry varies, but in practically all grain processing industries, the energy input versus energy in the product ratio is greater than 1 and for some operations, such as processed vegetables, the ratio may be as high as 15 to 1. The byproducts and residues from the production of cereals in the future may be required to provide all or at least part of this energy deficit. They have the potential to do so.

Summary. Energy conservation in agricultural production and processing has become of prime importance. Highly mechanized operations are necessary in order to provide the food and fiber for present and expanding U.S. and world populations at a feasible cost. Yet, these operations require large amounts of energy from fossil fuels to supplement that which agriculture can produce.

Energy costs, based on common fossil fuels, are rapidly increasing and are expected to continue to rise indefinitely. Stringent conservation is a must for the United States to remain competitive in world markets. Equipment must be modernized, designed and sized for the operation. Products must be based on functionality, rather than appearance. Processing operations must be held to an absolute minimum. Byproducts and residues must be utilized for food and fibers or for the production of heat. Energy must not be wasted as it has been in the past.

Literature Cited

1. Changes in Farm Production and Efficiency. A Summary Report. Statistical Bulletin No. 233. Economic Research Service, U.S. Department of Agriculture, June 1973.

2. Miller, D. L. Cereal grains as a source of industrial energy. In: Industrial Uses of Cereals. Edited by Y. Pomeranz, American Association of Cereal Chemists, St. Paul, Minnesota, pp. 252-261, 1973.

3. Miller, D. L. Cereals as a future source of industrial energy. Proc. Seventh National Conference on Wheat Utilization Research, Manhattan, Kansas, November 3-5, 1971. U.S. Department of Agriculture, ARS-NC-1, pp. 9-21, July 1972.

4. Economic Research Service. Private discussions. Unpublished.

SOFT WHEAT - AN ENDANGERED SPECIES?

D. M. Mennel
Mennel Milling Company

Buzz words and acronyms seem to be all the rage these days. The term "endangered species" comes to mind instantly when one hears about the whooping crane, the California condor, and the bald eagle, the American buffalo, the prairie chicken, Lake Erie pickerel, and so forth. Somehow or other I don't have the feeling that many of the people here would think of the term if I were to say "soft wheat."

Be that as it may, I am going to try to prove to you that soft wheat is in fact an endangered species. I am further going to try to prove to you that this is bad, not only from the sentimental viewpoint as is the case of the whooping crane, but also from a consumer preference and national economic cost-benefit ratio. I shall try to describe who raises, processes, uses and wants soft wheat. I may even try to suggest some solutions to the problem if I don't get carried away on a tidal wave of statistics.

For more than fifteen years I have been wearing out shoe leather within the halls of Congress and the nooks and crannies of that rabbit warren called the U.S.D.A., beating the drum for the fact that "wheat is not just wheat, but many kinds of wheat, suited best for the many different kinds of products demanded by the American consumer." I have presented my case in many different ways.

A few years ago, the National Soft Wheat Association presented the House and Senate Agriculture Committees packages of over two hundred different products containing soft wheat flour that we had picked up in a Washington supermarket. This is in marked contrast to the few types of bread offered in the same supermarket that used hard wheats, or the even fewer varieties of the pasta products using durum wheat.

I am not going to try to make a technical presentation of the merits of soft wheat for these many products. This year, of all years, the facts prove the case. Spring wheat has been delivered on Chicago futures in quantity because it is so much cheaper than soft. Kansas is troubled with low protein to the point that Kansas low protein can move all the way to the Eastern Seaboard and compete price-wise with locally grown soft wheats. Still bakers of soft wheat products are either insistent upon guarantees of 100% soft wheat in our flours, or are coming to us to help get them out of product problems created when they have succumbed to the seductively alluring price benefits of "soft-like" flours. I just don't believe it is necessary to prove further the desirability of soft wheat flours for many products.

It is true that there are certain products in which some amounts of other wheat flours can be blended. In fact, for example, certain doughnuts require a blend of soft and hard flours. I suggest in that case a flour made from either one or the other without the blend of both will create a mighty unsavory product.

It is equally true that, by use of some of the more esoteric and intricate technological innovations, small extractions of soft-like flour can be manufactured from almost any quality or variety of wheat. This is not to admit that economics or even practicality will allow such techniques to become widespread in the foreseeable future. This year is surely the year to try to capitalize on any and all such methodology and to gain experience that in any other supply-demand environment would be frightfully expensive to the experimenter.

From a practical viewpoint, it is only necessary to say that at a given protein level for flour, baking characteristics between hard and soft wheat products vary materially. Some very interesting work has been hinted at concerning the digestibility and assimilability of soft versus hard proteins. Taste as well as other physical characteristics of soft wheat products are materially different, even for very similar flours viewed from the usual laboratory analysis factors widely used in the industry.

Crackers become flinty, cookies become gummy, cakes become thick celled and heavy, doughnuts become greasy, pretzels become like welding rods, pie crusts become mucilaginous, gravy may lump, and creamed soups may coagulate when changes are made in the kind of wheat used in the milling process. Please note that many of the changes are introspective, not readily measured, and in fact are akin to beauty. We have a customer who claims its taste panel can detect as little as 10% hard wheat in a certain product. I am not saying some of these problems defy solution by the individual manufacturer. I am saying they exist, must be reckoned with, and most solutions are costly and only partially successful. I hope you will agree with me that the appetites of Americans will be satisfied best if we continue to raise soft wheat in sufficient quantity to meet the demand.

Let's now turn to a consideration of the kind of farmer who raises soft wheat, where he is located, what his options may be, and what kind of a job has been done over the years in supplying the need.

Ask any farmer west of the Mississippi what kind of a farmer raises soft wheat and you will get the stereotyped answer I have been fighting for many years. You will hear he is a little guy. Still using a mule and a piece of hard wood for a plow. Living on the home place. Putting out a patch of wheat when he can't think of something else to plant. Under earlier farm programs, you may remember the 15-acre exemption. This was anathema to the Western farmer. I have heard Western Congressmen claim that the 15-acre exemption was taking bread out of the mouths of their constituents. One thing they overlooked very conveniently was that the 15-acre exemptor also wasn't taking any money out of the Treasury.

Out of the millions of words emitted over the years about farm programs, there are some facts that should be said here. Apparently well over half of the farmers in the United States live east of the Mississippi River. I say apparently, because just last week I received the information from the Ohio Department of Agriculture that Ohio had just lost over 30,000 farms. 33,829 farms with feed grain base acreage and 12,373 farms with wheat allotments are being removed from the records of Ohio farms. This is a 23% reduction in the feed grain farms and a 12% reduction in the wheat allotment farms. Much of this loss stems from farm consolidation, from redefinition of a farm from urban sprawl, from highway construction, but I suspect a lot also comes from the changes in the farm program that requires better record keeping on the part of the Department.

Strangely enough, the reduction in the numbers of farms over the years seems to be very similar both east and west of the Mississippi. Everyone knows that farms are getting larger. The rate of growth west of the Mississippi is substantially higher than that in the East. For example, in a recent seven-year period, Ohio farm size grew by 7%, while in Kansas it grew 21%. There is an implication in this that will not be lost on the farm politicians I am afraid. Enough of demographics.

I realize all of you here are experts in wheat utilization, so I have not bothered to outline the geographic areas where the various types of wheat are grown. I'm sure you all know that the Mississippi River basically divides the wheat between the soft and hard, with the exception of the softs raised in the Northwest, and with numerous overlaps such as Arkansas soft and Illinois hard.

I'll bet some of you didn't know, however, that wheat was first planted in Ohio by Truman Guthrie of Marietta in 1788, using seed he had brought from western Pennsylvania. Wheat culture was negligible in Ohio until John Dent introduced the Old Red Chaff variety in Muskingum County in 1808, and that that was a soft variety. There now, if you get no other solid facts from my speech, you at least have those.

Before we leave the type of farmer who raises soft wheat, we should describe him further. The man has many other choices to make to best profit from his enterprise. Beans, corn, tomatoes, potatoes, cucumbers, sugar beets and forage crops all often bring higher returns per acre than wheat. Rye and oats even give him a fair return. Rotation is a way of life for him. He is farming high-priced land, using very high-priced equipment. He uses very little help in either putting his grain crops in the ground and in harvesting it. For the most part he does it himself, or sometimes with his wife to help him. He usually lives on one of the farms he works, and he normally works more than one farm. More often than not he is a college graduate, and he is a mighty canny businessman.

Let's look for a moment at production, disappearance, export and carryover. One thing that has been lost in the welter of noise over the Russian wheat deal of 1972 is the basic, fundamental data of wheat characteristics. Figure 1 provides a wealth of data that takes a long look--a forty-year look--at wheat production, domestic disappearance, export and carryover trends. It quits before we started to deal with the Russians. It is free of hysteria and doesn't blame a soul for what happened to wheat prices this year (1973).

The straight lines were prepared by the method of least squares, or if you prefer, by regression line analysis. This technique takes a lot of crooked lines and makes them straight and gives the appearance of respectability to otherwise confusing statistics. It has all the dangers of such simplifications, but over a forty year period it seems to me it might be valid. The data is all extracted from "The Wheat Situation."

Look at production for a moment. From 1930 to 1970, soft wheat production was absolutely flat. It was just under 200 million. Spring during the same period gained some--from 140 to over 200 million bushels. Hard wheat was something else again. Its line starts below 300 million and runs over 700 million.

Compare these lines with the lines for domestic disappearance. As most of you know, the drop in per capita consumption of wheat flour has been paralleled almost exactly by the rise in the population in this country. Domestic disappearance of all three types of wheat is practically flat. In fact, the soft line shows a slightly declining trend. This appears to be caused by the fact that wheat ceases to be fed when its price gets too high over the price of corn, and soft wheat has been very scarce some years, so in short years it is not fed and the domestic consumption declines. The lines for soft and spring show a normal consumption of around 150 million bushels, while hard boasts about 300 million. In other words, soft and spring together amount to about the same demand as hard over the long pull.

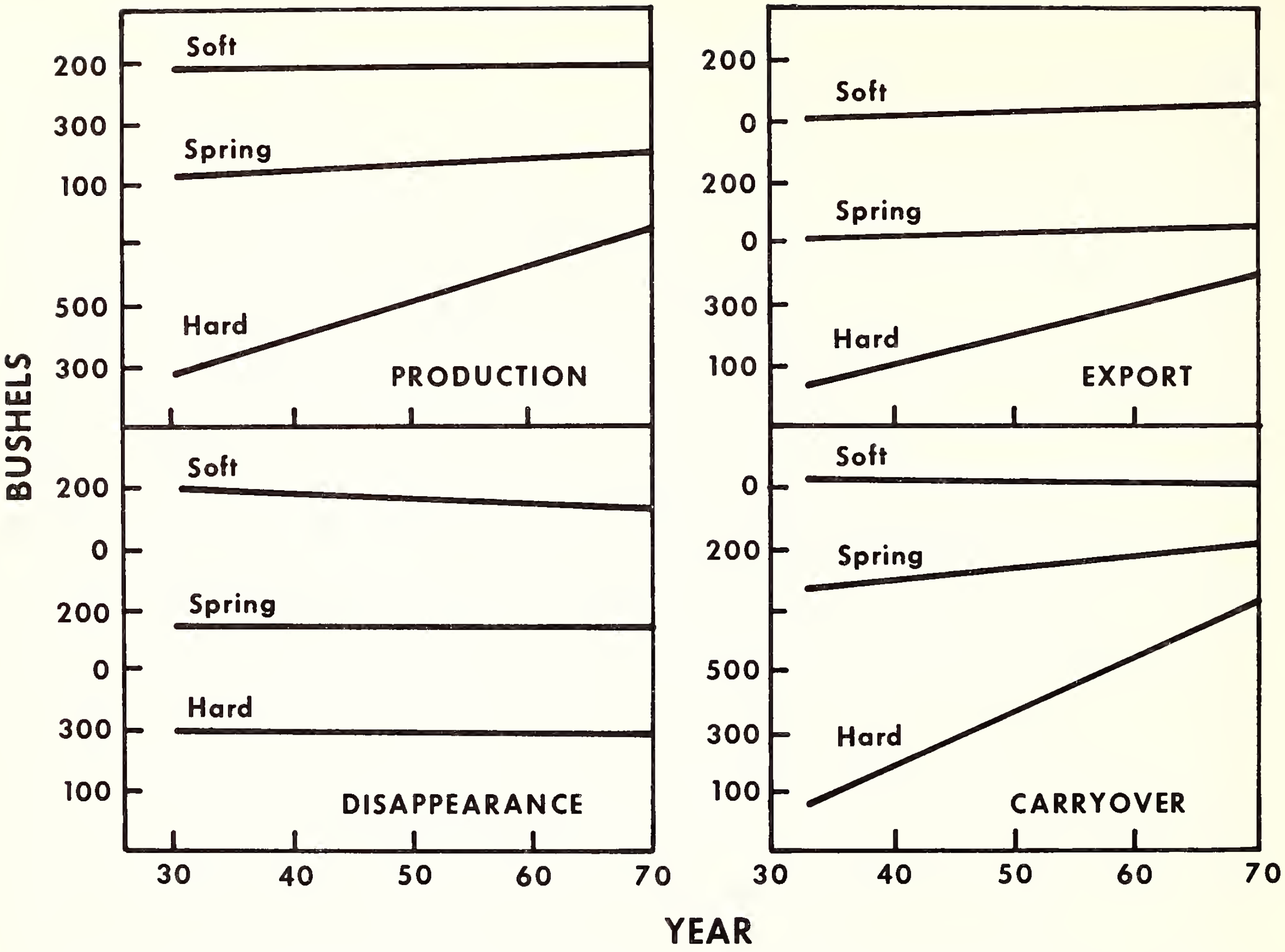


Figure 1. Trend lines (by least squares method) for production, domestic disappearance, exports and carryover for soft, spring and hard wheats for the years 1930-1970.
Source: "Wheat Situation;" USDA.

Now we come to export. This is another paragraph of the same story. The soft and spring lines rise slowly from nothing in 1930 to around 50 million bushels, but hard rises from nothing to nearly 400 million bushels. Please remember these are trend lines.

The only figure we have left to consider is the carryover. Again, the same picture emerges--remember, we are looking at a forty-year period by least square lines. The soft carryover line is flat--around 25 million, which happens to be the average of the whole period. The highest during this span was 70 and the lowest 4 million bushels. Spring moved slowly from below 100 to over 200 million bushels. Spring went from a low of 17 million in 1936 to a high of 251 million in 1958 and was not below 100 million for the last 20 years. Now we come to good old hard. The regression line for its carryover starts around zero and rises to over 700 million bushels. The actuals show wild gyrations. The lowest carryover during the forty years was in 1945 with 37 million, and the highest was 1,104 million bushels in 1960.

When you remember that during this long period we spanned the Roosevelt era, World War II, and come down to the pre-Russian period, some facts seem very clear to me. The American consumer is not eating wheat products year after year in about the same amount, regardless of the source of the wheat, _if_ you can believe in statistics. A majority of farmers are raising wheats needed by American consumers. The vast majority of the cost of wheat export programs, wheat storage programs, county support loans and the wheat economy in general has been spent for hard wheat, not spring, and even less for soft.

I have tried other means of looking at this condition. Table 1 shows the production, domestic use, export and carryover data for 15 years of soft red winter wheat. Table 2 shows the yield in bushels per acre for 15 years for the principal soft wheat States. Table 3 shows the production of all wheat in the same eight States. Table 4 shows the carryover of the various wheat types for five years calculated in terms of weeks of domestic demand. This table scares me every time I look at it.

Table 1. Data on soft red winter wheat (millions of bushels). Source: USDA, ARS.

Crop Year	Carryin	Production	Supply	U.S. Use	Export	Total Use	Carryover
1958-59	6	192	198	134	43	177	21
1959-60	21	156	177	127	40	167	10
1960-61	10	190	200	134	54	188	12
1961-62	12	202	214	134	56	190	24
1962-63	24	156	180	134	41	175	5
1963-64	5	218	223	135	84	219	4
1964-65	4	223	227	140	80	220	7
1965-66	7	185	192	139	45	184	8
1966-67	8	217	225	142	68	210	15
1967-68	15	274	289	138	121	259	30
1968-69	30	224	254	171	50	221	33
1969-70	33	194	227	176	28	204	23
1970-71	23	174	197	156	26	182	15
1971-72	15	212	227	166	43	209	18
1972-73	18	227	245	166	70	236	9
1973-74	9	162	171	--	--	--	--

Table 2. Yields (bushels per acre) of all wheat in the principal northeastern soft wheat States. Source: USDA, ERS.

State	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Ave.
NY	30.0	30.0	34.0	35.0	37.0	37.5	37.0	42.0	40.0	40.0	43.0	43.0	40.0	41.0	39.0	37.9
NJ	31.5	33.0	33.0	33.0	28.5	34.5	36.5	40.0	39.0	35.0	38.0	38.0	38.0	41.0	40.0	35.9
Pa	26.5	29.5	30.0	28.0	31.0	32.0	35.0	36.0	36.0	32.0	36.0	37.0	34.0	37.0	34.0	32.9
Ohio	24.5	35.0	31.0	32.0	38.0	32.0	32.0	39.0	34.0	37.0	36.0	39.0	38.0	45.0	37.0	35.2
Ind	26.0	33.0	34.0	34.0	40.0	34.0	32.5	44.0	37.0	35.0	39.0	40.0	39.0	47.0	42.0	37.1
Ill	26.0	29.0	36.0	32.5	40.0	36.0	35.5	41.0	39.0	36.0	37.5	40.0	38.0	47.0	36.0	36.6
Mich	32.0	31.5	36.0	33.0	38.0	40.0	33.0	40.0	36.0	36.0	38.0	40.0	38.0	38.0	39.0	36.6
Mo	25.0	28.5	30.5	27.0	33.0	31.5	27.5	34.0	32.0	33.0	39.0	34.0	33.0	39.0	32.0	31.9

Table 3. Production (millions of bushels) of all wheat in the principal northeastern soft wheat States. Source: USDA, ERS

State	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
NY	7.6	7.4	8.3	6.4	7.5	7.6	6.8	7.4	10.0	8.5	7.8	6.6	5.4	6.7	5.5
NJ	1.4	1.5	1.4	1.2	1.0	1.3	1.4	1.6	2.0	1.5	1.3	1.2	1.2	1.4	1.6
Pa	14.0	15.8	15.7	12.6	15.0	14.8	14.3	14.4	17.3	12.6	12.1	10.7	9.6	11.2	9.0
Ohio	31.0	50.0	45.2	39.6	55.5	46.3	40.3	46.1	51.5	45.4	38.4	37.9	36.9	47.7	23.2
Ind	31.6	40.6	43.9	39.9	53.1	47.4	36.2	42.2	48.4	35.5	35.6	30.9	27.8	39.4	27.9
Ill	43.2	45.7	60.2	51.4	71.4	69.4	56.8	58.4	76.6	53.1	50.4	41.1	37.4	54.5	42.3
Mich	35.6	33.6	40.0	30.1	39.5	38.6	26.5	30.5	40.3	31.9	24.2	22.8	21.2	21.9	21.1
Mo	38.0	37.6	41.9	26.4	40.3	47.3	32.6	41.1	53.8	42.2	31.4	31.7	27.7	37.1	24.3

Table 4. Wheat carryover in weeks of domestic demand

Crop Year	Hard Winter	Hard Spring	Durum	White	Soft Red
1972/73	26	50	67	10	3
1971/72	58	106	95	18	6
1970/71	66	63	84	15	5
1969/70	86	68	119	45	7
1968/69	75	84	56	36	10
Weighted Average	62	73	84	22	6

If you make the daring assumption that a year contains 52 weeks, and so divide the official domestic disappearance of each type of wheat by 52, this gives you a weekly disappearance, which you then divide into the official carryover, and you find out how many weeks you can last from July 1st each year before you officially run out of wheat unless some gets harvested.

Last July 1, 1973, for example, we carried over enough hard winter wheat to last us through New Year's Eve, enough spring to get us halfway between Memorial Day and the 4th of July, enough durum to get us past Labor Day of next year, enough white to stretch until after Labor Day of this year, and not quite enough soft red to last until the first of August. Please remember this is a statistical supply and doesn't include any exports whatsoever. In fact, in the last five years, only once did we have enough carryover of soft red wheat to last us until Labor Day, and then it wouldn't have lasted us through September.

For the last few minutes I have been talking about data that is older than many of my audience. Let's bring it up to this instant.

As of September 1, 1973, the indicated production of soft red winter wheat is 162,477,000 bushels. This low quantity was the result of rains last fall, rains this spring, and rains this spring, and rains this spring. This was down over 64 million bushels from 1972. If we use my 40 years trend line for domestic disappearance of around 150 million, we have 12 million to add to the official 9 million carryover from last year for a total of 21 million for export and carryover. If we take the last 5 years average of 167 million, we have a negative 4.5 million carryover to add to the 9 million carryover to show 4.5 million for export and carryover. If we take a 10-year average domestic disappearance, it is 166.3 million, giving us nearly 13 million carryover and export.

On August 31, 1973, the Department of Agriculture inspections of wheat exported to that date showed 15.2 million bushels. The latest release including the week ended September 21, 1973, shows the inspection to be 18,378,000. This does not include the undelivered commitments about which the Department has made much of late. The export year is only one quarter over. The inescapable conclusion that I must draw is that soft wheat and its products are going to disappear before the end of this crop year.

Is soft wheat an endangered species? I think it is.

We as millers have been asked to step up like little men and bid competitively for our supplies. There have been authenticated reports of 95¢ over Chicago December being paid recently and semi-authenticated reports of 125¢ over Chicago March for March delivery being paid for soft red wheat in the last month. I think we are doing our bit for the farm economy.

It seems to me that all the half doors in the stable are hanging ajar, and a short candle is not so slowly burning in its nest of straw in the haymow. If exports of soft wheat are not restricted soon, the watchword will be "Let 'em eat bread."

THE WHEAT SITUATION AND OUTLOOK

James Naive
Economic Research Service, U.S. Department of Agriculture

1973/74. Despite a record 1973 harvest, low beginning stocks and strong demand will result in a further drawdown in wheat stocks at the end of the 1973/74 marketing year. Strong foreign demand and uncertainties about exportable supplies throughout the world have set the stage for heavy early-1973-season commitments and exceptionally strong harvest prices.

The 1973 wheat crop was indicated at a record 1,727 million bushels, 12% above last year. But carryover into the new crop year was the lowest since 1967 and the total supply for the current season is estimated to be down 10%.

Domestic disappearance may edge lower if less wheat is fed. But wheat exports could approach last year's phenomenal level of 1,184 million bushels. Soviet wheat purchases from the United States are expected to be down sharply from the estimated 400 million bushels of 1972/73, but sales to the People's Republic of China and India will be sharply larger. Total domestic use and exports for the season will likely exceed production, resulting in another reduction in carryover at the end of the 1973/74 season to around 300 million bushels.

Mid-September 1973 farm prices of wheat averaged $4.62 per bushel, the highest monthly farm price on record. With continued heavy export demand, farm prices are likely to remain very strong.

Forecasts indicate a record world wheat crop, up about 10% from last year's reduced level. Recovery is expected in the USSR and Australia, and expanded acreage has pushed production up in the United States and Canada. World wheat trade in 1973/74 is expected to be down modestly from last year's record level. This is primarily due to anticipation of smaller purchases by the Soviet Union. Stocks of the major exporters are down for the third straight year to the lowest levels since the 1950's, adding fuel to the already hot price situation. Chances for any substantial stock buildup appear slim.

1974/75. With the enactment of the Agricultural and Consumer Protection Act of 1973 and the announcement of the 1974 wheat and feed grain programs, one of the basic factors for grower's planting decisions has been set. The following are the major program provisions:

1) No set-aside requirements
2) No planting restrictions on conserving base
3) Loan rates
    a) Wheat--$1.37 per bushel
    b) Corn--$1.17 per bushel
    c) Sorghum--$1.05 per bushel
    d) Barley--$.90 per bushel
    e) Oats--$.54 per bushel
4) Target prices
    a) Wheat--$2.05 per bushel
    b) Corn--$1.38 per bushel
    c) Sorghum--$.90 per bushel
    d) Oats and rye--none
5) Allotment or pay base
    a) Wheat--55 million acres
    b) Feed grains--89 million acres

Strong prices are expected to push wheat acreage and production higher in 1974, offsetting the reduced carryin expected for 1974/74 and boosting the supply for the season. Assuming that total use may change only a little, carryout could increase around 100 million bushels.

THE WHEAT SITUATION AS SEEN BY AN AGRONOMIST

L. P. Reitz
National Program Staff, Agricultural Research Service,
United States Department of Agriculture

Since 1967 the U.S. has produced five wheat crops, each exceeding 1.5 billion bushels. This was done on an acreage only two-thirds that seeded to wheat in the 1940-50's. Research on productivity, stability, and efficiency has made major contributions to the U.S. farmers' capability to produce. A 10-percent increase in yield per acre has been projected, which seems attainable by 1980. Further progress in reducing losses from diseases, insects, and natural hazards seems assured.

Some people say we should double wheat production. This is a complicated problem to solve because it involves major shifts in land use, increased inputs of fertilizer, and more use of irrigation. In recent years we have had 50 million acres of idle crop land or land in cover crops. If all of this was seeded to wheat and recent average yields were obtained, this alone would double our production of wheat. This is not likely because the demand for other crops is as great as that for wheat. There remains the land in farms used only for pasture and nonfarmland that might be developed. Much of this is third- or fourth-class land from which only low yields or intermittent wheat crops could be expected.

Our wheat is of greater worldwide interest now than it has ever been. I foresee an alternation of national shortages with surpluses. The interval between these extremes has been 5 to 14 years since 1937. I would expect this interval to shrink to 2 to 10 years.

Late last summer (July 25, 1973), The Kansas City Star carried a story about how research had boosted Kansas wheat farmers' income by $300 million this year. The story was credited to F. W. Smith, Director of the Kansas Agricultural Experiment Station. Roy Freeland, State Secretary of Agriculture, took him to task for making his estimate too conservative.

Whatever the real facts are, I would say the boost from research has been sizeable, and it was about time. Farmers have suffered from the cost-price squeeze for at least two decades. Farmers, farm organizations, associated industry, and legislators have supported and spoken for increases in research on wheat all the way from production to marketing and utilization research. People representing these groups believe there has not been as much support as was justified by the gains to be achieved. However, we have many calls on our tax dollars, more than we can meet. I have no complaint about the assignment of priorities. It is a tough job. Hindsight - the critics favorite platform - may show that we should have supported other things. Agricultural research, as illustrated by the progress of the last century, provides a phenomenal success story. I am glad to be a part of it.

The U.S. produced its first 1.5 billion bushel wheat crop in 1967 (Table 1) and even with low prices, farm income from the crop exceeded $2 billion (1). We have now produced five crops exceeding 1.5 billion bushels - with 1973 the largest ever. These large crops have been produced on an acreage only two-thirds that seeded to wheat in the late 40's and early 50's when production never exceeded 1.3 billion bushels.

Table 1. U.S. wheat acreage and production; Source: USDA.

Year	Harvested Acres	Yield, Bushels per acre	Yield, Bushels Total	Farm Value, Billions
1967	58,771,000	25.9	1,522,382,000	$2.1
1970	43,564,000	31.0	1,351,558,000	1.8
1971	47,674,000	33.9	1,617,789,000	2.2
1972	47,301,000	32.7	1,544,775,000	2.6
1973[1]	53,588,000	32.6	1,748,533,000	-

[1] Preliminary

Production of wheat has become increasingly efficient (Table 2). I remember the way we grew wheat in my late teens and can vouch for the estimate that 100 hours of labor were needed to produce 100 bushels of wheat. It seems incredible that only 9 hours are needed now and that for many growers even fewer hours are needed.

Table 2. Manhours per unit of wheat production in the U.S.; Source: Agr. Statistics, USDA, 1972.

Years	Manhours per - acre	Manhours per - 100 bushels	Yield Bushels per Acre
1910-14	15.2	106	14.4
1945-49	5.7	34	16.9
1965-69	2.9	11	27.5
1970-71[1/]	2.9	9	32.5

[1/] Preliminary.

The long-time trend in wheat yields tells part of the reason for the increase in efficiency (Figure 1).

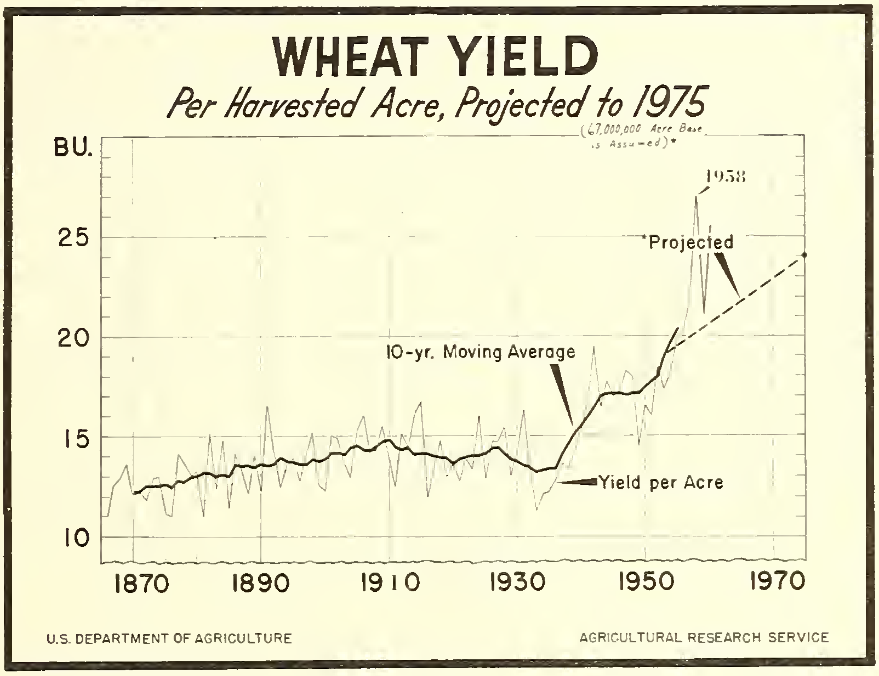


Figure 1. Wheat yield trends in the U.S., 1866-1959, with a projection to 1975 based on the use of 67,000,000 acres.

The average yield has doubled. The 10-year moving average (heavy line) smooths the annual fluctuations and provides a trend line. The dotted line is a yield projection made in 1953 by USDA economists. At the time, agronomists (including me) thought the projection was optimistic and "toned down" the projection. We were too conservative. The 10-year average for the decade just closed at 28.7 bushels per acre and for the four preceding 10-year moving average periods, yields were 27.9, 26.9, 26.4, and 25.5 bushels per acre. Recently the Economic Research Service has made some new projections (Table 3)(2).

Table 3. Projections of U.S. crop yields by ERS, USDA.

Year	Yield per acre, bushels Wheat	Barley	Oats	Sorghum	Corn	Yield per acre, lbs. Rice
1971	33.8	45.6	55.7	53.9	86.8	4630
1980	36.2	55.0	62.5	64.0	105.0	5300

Note that a 10-percent rise in wheat yields is indicated, whereas a 12- to 25-percent rise is projected for the other cereal grains. Such projections are based on many assumptions--average weather, no unsuspected disease or insect threats, stable competitive relationships, and adequate fuel and industrial products. Has research provided or will it provide the basic ingredients whereby improvements in technology justify such increases? Yes, I think research has provided many of these ingredients and will continue to add to them. Of course, many factors are involved.

Others will speak more fully on the world situation, but we should look briefly at the global picture to help orient us here at home. Wheat production is being pushed in most countries. The result (Table 4) is astounding (3). Since the early 60's, world wheat production has increased approximately 50 percent, and the projection to 1980 indicates an increase of another 25 percent. Notable advances are being made in many countries. Take India for example (Figure 2); the improvement in yield has been very dramatic (4).

Table 4. World wheat crop; Source: USDA.

Years	Billion Bushels	Million Metric tons
1960-64	8.5	231.7
1969-71	11.6	317.9
1980 projection	14.6	398.2

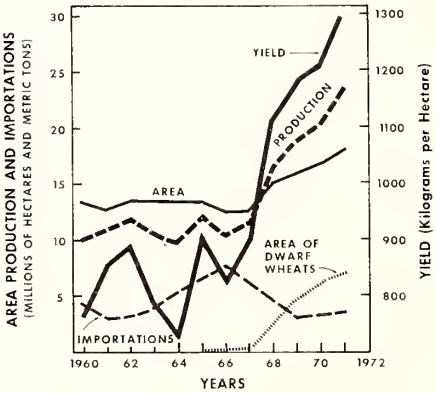
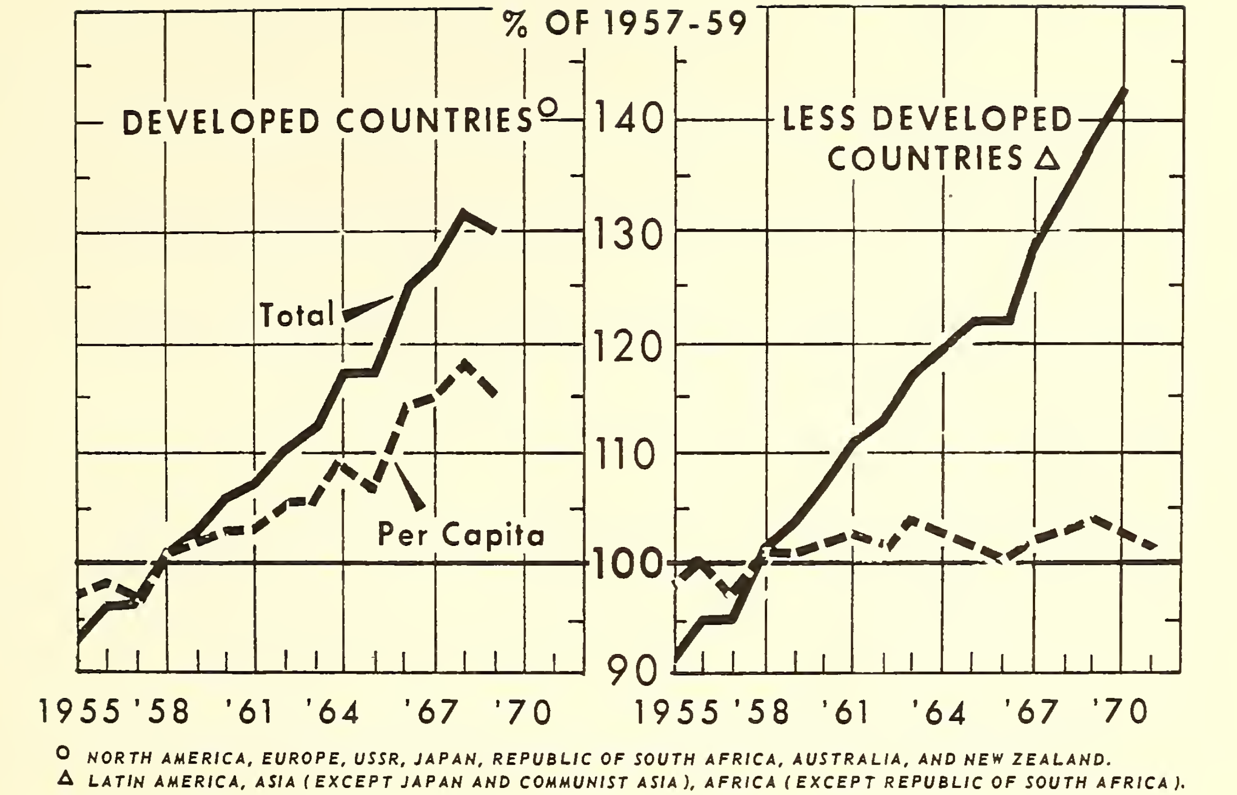


Figure 2. Total area, production, yield, dwarf acreage and importations of wheat in India, 1960-1971. Source: Official government figures.

The real need, however, is better depicted by per capita changes in agricultural production (Figure 3). The sobering fact is that the most per capita gains have been made in the developed countries (5).

The most publicized and probably the most important single technological improvement worldwide is the introduction of strongstraw, fertilizer-responsive varieties of wheat (6). Research in India illustrates responses in 11 varieties (Figure 4) (7). At low-yield levels, weak and strong varieties show small differences, but at high-yield levels, the advantage for responsive varieties is impressive. This principle was first demonstrated by semidwarf varieties in the Pacific Northwest of the U.S., then in Mexico, and now in most wheat-growing countries. I sometimes say the rest of the world has finally learned what Japanese farmers knew before 1875. They had semidwarf wheat even then (6). However, varieties do not need to be semidwarf in stature to be responsive. Varieties of moderate height with proper straw and plant characteristics may do as well as or even better than semidwarfs in many situations. Results of the International Winter Wheat Performance trials bear this out (8), in addition to variety trials in many of our States.



U.S. DEPARTMENT OF AGRICULTURE NEG. ERS 4750-70 (9) ECONOMIC RESEARCH SERVICE

Figure 3. World agricultural production--total and per capita relative changes based on the 1957-1959 period.

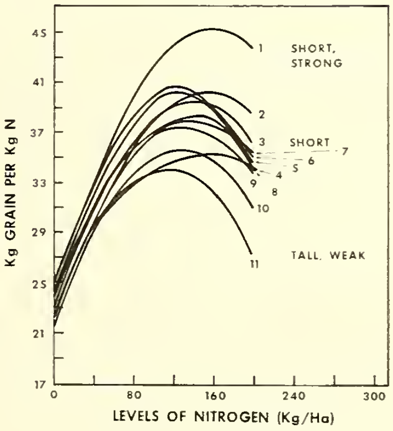


Figure 4. Response of eleven varieties of wheat to nitrogen application in India.

So much has been said about the "green revolution" that it might be well to examine the ingredients that contributed to its success and the research needed to undergird it (Table 5).

Table 5. Ingredients of a green revolution.

1. Better Nutrition of Plants
   - Timely tillage (mechanization)
   - Chemical and organic fertilizers
   - Farm manures and legumes
2. Water Conservation and Irrigation
   - Save rain and soil
   - Control weeds
   - Irrigate (when feasible)
3. Improved Varieties
   - Bred for vigor
   - Adapted to locality
   - Resistant to pests
4. Control of Pests
   - Host plant resistance
   - Judicious use of chemicals
   - Crop management
5. Simultaneous Adoption of Practices
   - Eliminate multiple hindrance
   - Balance ingredients
   - Mix well with Courage, Zeal, Hope

If any one of these five groups of factors is missing, the movement not only grinds to a halt but also may retrograde to previous low-yield levels.

As we look ahead, it is appropriate to examine the potential for further improvement in wheat and other crops. I will use a chart done in 1967 (Figure 5) as a point of reference (9).

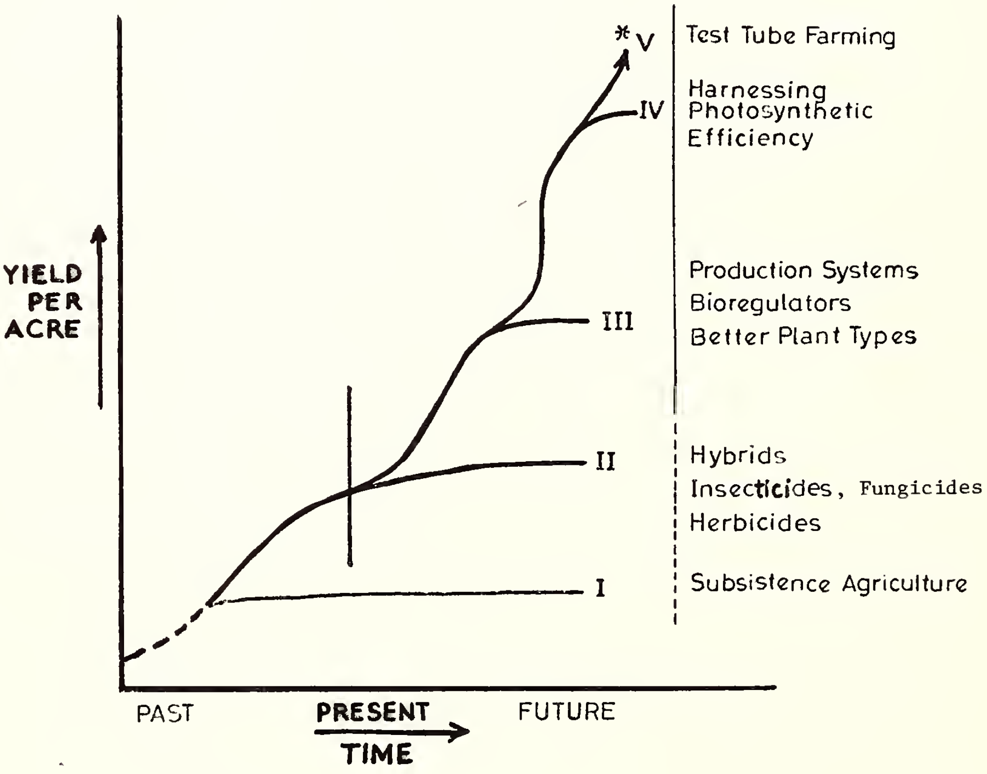


Figure 5. Increasing sophistication and complexity in food production (9).

We have moved a long way from subsistence agriculture, stage I on the chart. We are exploiting many of the technologies represented by stages II and III but not all of them. Corn and sorghum technology is perhaps more advanced than that for small grains. Research on wheat is active in stages II, III, and IV. "Test tube" farming seems a long way off, but those who have studied potentials for food production say man will be crowded off or choked off the planet before he is starved off. This assumes we give the needed attention to the ultimate in food production. It will not "just happen."

The immediate research job ahead is rather like what has been emphasized for a long time. It takes a lot of work to prevent falling back to previous low production levels. Losses in agriculture (10) for a recent decade showed how far we are below our potential (Table 6). I do not have an official estimate for the 1970's but am confident the losses would be less for diseases and weeds, but the other losses would be about the same.

Table 6. United States wheat--percentage reduction from potential due to various factors.
Source: 1951-60, (10); 1964-73, author estimate.

Factor	1951-60	1964-73
Diseases	14	11
Weeds	12	9 [1]
Insects	6	5 [2]
Harvest loss	5	5
Storage and processing	4	4
Violent weather	-	5

[1] Does not include cost of chemical control.

[2] Includes mites and nematodes.

I am greatly concerned about the continuing losses from diseases, especially the rusts (11). Wheat is highly vulnerable to them. Several other leaf diseases cause considerable losses. Viruses continue to take their toll, with sources of resistance located mainly in the relatives of wheat, and such resistance is hard to transfer. Is smut coming back? It could.

Old weeds, e.g., wild oats, bindweed, etc., and new weeds, e.g., false chamomile and new foxtails, keep us busy.

New races of hessian fly keep entomologists and breeders on the watch; and the cereal leaf beetle, a major threat in Michigan and Indiana, keeps spreading east, south, and west. Where will it stop?

Harvest, storage, and handling losses are researchable problems. Some will say you can't breed for resistance to violent weather, but I say it can be done. Winterkilling took a heavy toll last year in our Pacific Northwest. However, data supplied to me by D. W. George, ARS Agronomist, shows conclusively that a number of germplasm sources have tolerance to that kind of violent weather. We see the depredations of erosion to our lands. Again, this is partly solvable by research on better varieties and management practices. It is high time we got "with it."

Mostly I have talked about maintaining or improving the yield per acre. The projection earlier was to increase the yield 10 percent or 3 bushels per acre. In recent years we have used about 50 million acres and from this base, a 3-bushel increase would increase national production by 150 million bushels. Such an increase would be about equal to half the production of Kansas alone or half the production of Montana, Idaho, Oklahoma, and Texas combined.

Some estimates call for double our present production. Of course, if we doubled our acreage and held yields constant, it could be done. The extra acres would come from idle land, from land used for other crops, or by seeding land normally fallowed. In the late 1940's we harvested 27,900,000 acres more wheat than in the early 1970's (Table 7). If we restored that land to wheat at 1970 yields, we could produce 893 million extra bushels of wheat. In the major wheat States, water would be a limiting factor in the realization of high yields comparable with those obtained after fallow. In humid areas, there would be competition for land now used by important crops such as feed grains, soybeans, and pasture for livestock. It is obvious to me that far too many assumptions have been made regarding the ease with which we might double wheat production and increase feed and oil crops at the same time. Among other things we must look at fuel, fertilizer, farm chemicals, and machinery. First of all, not last, we should look to the research needed to provide new technology required to meet these higher production goals. In ARS we have lost personnel since 1964 and I believe this is true also for most, if not all, of the wheat States.

Nor can we be complacent about quality. After all, wheat is unique mainly because of its nutritive value in foods made directly from the grain without passing through livestock. It must remain free of

Table 7. Acres of wheat harvested in the late 1940's compared with the early 1970's, by divisions and total for the U.S.

Division	Harvested Acreage		Decrease
	Late 1940's	Early 1970's	
North Atlantic	1,400,000	500,000	900,000
North Central	42,000,000	27,000,000	15,000,000
South Atlantic	1,800,000	800,000	1,000,000
South Central	14,000,000	7,000,000	7,000,000
Western	15,000,000	11,000,000	4,000,000
U.S. Total acres	74,200,000	46,300,000	27,900,000[1/]
Total bushels	1.2 billion	1.5 billion	--

[1/] 27,900,000 x 32 bushels per acre = 893 million bushels.

contaminants such as ergot and molds; it must not sprout or go out of condition in the handling process; the grain must be readily millable; and the flour must make a uniformly high-quality loaf of bread, cake, or other food product. Research is very promising on improved nutritional value wherein both protein level and amino acid balance may play a part (12).

Finally, I would like to pay tribute to one of the most famous varieties of wheat ever to be introduced into the United States. It is the 'Turkey' variety. It has been with us 100 years, and although not grown much anymore, it was truly the cornerstone of an empire--the hard red winter wheat belt. Today most varieties of this class trace by lineage to Turkey. We owe a debt to the unknown plant breeders under whose keen eyes this variety was developed and to those hardy pioneers who endured hardships, which many of us cannot imagine, to make this bequest to us who have followed (13).

Literature Cited

1. U. S. Dept. Agr., Agricultural Statistics, 1972.

2. Address by Robert W. Long, Asst. Sec., U. S. Dept. Agr., May 16, 1973. USDA 1558-73.

3. Address by Don Paarlberg, Director of Agr. Econ., U. S. Dept. Agr., Jan. 22, 1973. USDA 191-73.

4. CIMMYT 1970-71 Annual Report on Maize and Wheat Improvement, p. 41.

5. U. S. Dept. Agr., Economic Res. Service.

6. Reitz, L. P. New wheats and social progress. Science 169:952-955, 1970.

7. Swaminathan, M. S. Five years of research on dwarf wheats. India Agr. Res. Inst., p. 12, 1968.

8. Stroike, J. E., and V. A. Johnson. Winter wheat cultivar performance in an international array of environments. Neb. Agr. Res. Bull. 251, 1972.

9. Parthasarathy, N., and S. S. Rajan. Plant breeding strategy for the seventies with special reference to developing countries in the tropics. Int. Rice Comm. Newsletter 21(4):1-17, 1972.

10. U. S. Dept. Agr. Losses in Agriculture. Agr. Handb. 291, 1965.

11. Reitz, L. P. The worst diseases of crops: Wheat. Crops and Soils p. 14-17, Nov. 1972.

12. Johnson, V. A., A. F. Dreier, and P. H. Grabouski. Yield and protein responses to nitrogen fertilizer of two winter wheat varieties differing in inherent protein content of their grain. Agron. J. 65:259-263, 1973.

13. Quisenberry, K. S., and L. P. Reitz. Turkey wheat--The cornerstone of an empire. Agr. History, Jan. 1974 (in press).

ATTENDANCE LIST

Donald C. Abbott
Biochemistry Dept.
Oklahoma State University
Stillwater, OK 74074

Maher M. Abou-guendia
General Mills Chemicals, Inc.
2010 E. Hennepin Ave.
Minneapolis, MN 55413

Orville J. Banasik
Dept. of Cereal Technology
N. Dakota State Univ.
Fargo, ND 58102

Quentin D. Banks
Colorado State University
2490 W. 26th Ave., Rm. 240
Denver, CO 80211

Howard C. Becker
Conagra Inc.
200 Kiewit Plaza
Omaha, NE 68131

Robert Brastrup
Montana Res. and Marketing Comm.
P.O. Box 3024
Great Falls, MT 59403

Robert H. Breithaupt
Milling & Baking News
4800 Main St., Rm. 650
Kansas City, MO 64112

Lee Bronson
Colorado Wheat Admin. Comm.
1636 Welton Street
Denver, CO 80202

Jim Coddington
USDA-AMS-Grain Division
6525 Belcrest Rd., Rm 744
Hyattsville, MD 20782

Dr. R. Daftary, Ph.D.
ADM Research Dept.
P.O. Box 1470
Decatur, IL 62525

Jones J. Davidson
Burrus Mills
P.O. Box 1687
Fort Worth, TX 76101

Ray Davis
National Assoc. of Wheat Growers
Potter, NE 69516

James H. Dietz
P V Tech Center
760 Grain Exch.
Minneapolis, MN 55415

Donald K. Dubois
The Paniplus Co.
3414 E. 17th St.
Kansas City, MO 64127

G. J. Dunne
Industrial Grain Products, Ltd.
P.O. Box 6089
Montreal, Canada

Malcolm Fargher
Oregon Wheat League
Dufur, OR 97021

Peter Fisher
3235 16th S.W.
Seattle, WA 98134

Duane Foote
University of Nebraska
325 Keim Hall, East Campus
Lincoln, NE 68503

Walter L. Gagen
John Labatt Ltd.
150 Simcoe St.
London, Ontario 88
Canada

John W. Giertz
Ross Industries
P.O. Box 2696
Wichita, KS 67201

Vance Goodfellow
Crop Quality Council
828 Midland Bank Bldg.
Minneapolis, MN 55401

Kurt Gutgreund
IIT Research Institute
10 West 35th St.
Chicago, IL 60616

Mr. Michael Hall
Great Plains Wheat, Inc.
Suite 340
Washington, DC 20005

Paul Hammes
Mercek and Co.
Rahway, NJ 07065

Merle Hedland
North Dakota State Wheat Comm.
P.O. Box 956
Bismarck, ND 58501

Verl E. Headley
CPC - International
Moffett Technical Center
P.O. Box 345
Argo, IL 60501

L. O. Helmer
Burrus Milling Dept.
Cargill Incorporated
P.O. Box 1687
Ft. Worth, TX 76101

Wynne B. Henderson
Idaho Wheat Growers
Nezperce, ID 83543

Wayne Henry
FAR-FAR-CO
960 Holstead
Hutchinson, KS 67501

Frank Hepburn
American Institute of Baking
400 E. Ontario Street
Chicago, IL 60611

William J. Hoover
Food & Feed Grain Institute
Kansas State University
Manhattan, KS 66504

Irwin Hornstein
Office of Nutrition
Agency of International
Development
Washington, DC 20523

Henry S. Ikeda
AMS,USDA
Bldg. 306, ARC
Beltsville, MD 20705

Frank Johannsen
Nebraska Wheat Growers
Bayard, NE 69334

John A. Johnson
Dept. of Grain Science & Industry
Kansas State University
Manhattan, KS 66502

Constance Kies, Professor
Dept. of Food & Nutrition
University of Nebraska
Lincoln, NE 68503

Keith Kilander
Midwest Solvents Co., Inc.
1300 Main Street
Atchison, KS 66002

Marx Koehnke
Nebraska Wheat Division
620 Terminal Bldg.
Lincoln, NE 68508

John Konecny
Centennial Mills, Inc.
P.O. Box 3773
Portland, OR 97208

George Kubik
North Dakota State Wheat Comm.
316 North 5th St.
P.O. Box 956
Bismarck, ND 58501

Glenn Lorang
Farm Journal
541 Sinton Ave.
Colorado Springs, CO 80906

Klaus Lorenz
Food Science and Nutrition
Colorado State University
Fort Collins, CO 80521

J. A. Maga
Dept. of Food Science &
Nutrition
Colorado State University
Fort Collins, CO 80521

William C. Mailhot
General Mills Inc.
9200 Wayzata Blvd.
Minneapolis, MN 55426

Mr. Clayton S. Manness
Canada Grains Council
Suite 400
177 Lombard Ave.
Winnipeg, Manitoba R3B OW5

Lawrence F. Marnett
C. J. Patterson Co.
3947 Broadway
Kansas City, MO 64111

Cap Mast
Millers National Federation
14 E. Jackson Blvd.
Chicago, IL 60604

Paul J. Mattern
University of Nebraska
202 KCR Bldg.
College of Agriculture
Lincoln, NE 68503

Reginald Meade
Pillsbury Company
1421 North First Street
Stillwater, MN 55082

Donald Mennel
Mennel Milling Co.
P.O. Box 806
Fostoria, OH 44830

Peter Meredith
Wheat Research Institute
Department of Scientific and
Industrial Research
197 Hereford St.
Christchurch, New Zealand

Robert W. Merten
Colorado Dept. of Agriculture
1525 Sherman Street
Denver, CO 80203

Nervin W. Meyer
Protein Research & Development
Miles Laboratories, Inc.
Elkart, IN 46514

Warren G. Miller
South Dakota Wheat Commission
Box 549
Pierre, SD 57501

George K. Minor
Colorado Milling & Elevator Co.
1200 Lincoln St.
Denver, CO 80201

Dr. Kay E. Miskin
Funk Seeds International, Inc.
1300 W. Washington St.
Bloomington, IL 61701

Milton Morgan
4500 Hulbert Rd.
Junction City, OR 97448

Eugene Morris
Vitamin and Mineral Lab
Nutrition Institute, ARS, USDA
Agricultural Research Center
Beltsville, MD 20705

Paluri R. Murthy
Peavey Co.
11 Peavey Rd.
Chaska, MN 55318

James Naive
ERS, USDA
500 12th St., S.W.
Washington, DC 20250

R. O. Nesheim
Quaker Oats Co.
John Stuart Research Lab
617 West Main St.
Barrington, IL 60010

John M. Newton
Clinton Corn Processing Co.
Clinton, IA 52732

J. R. Perrozzi
The Pillsbury Company
311 Second St., S.E.
Minneapolis, MN 55414

Arlee Phillips
Nebraska Wheat Commission
Hemingford, NE 69348

Don Pingree
Deklab Agresearch, Inc.
2213 First Avenue North
Fargo, ND 58102

Dr. Y. Pomeranz
Grain Marketing Res. Center
ARS,USDA
1515 College Ave.
Manhattan, KS 66502

D. B. Pratt, Jr.
The Pillsbury Co.
608 2nd Ave., South
Minneapolis, MN 55402

Hal C. Ransom
The Pillsbury Company M 385
608 Second Avenue S.
Minneapolis, MN 55402

Peter M. Ranum
W & T Flour Service Lab
Pennwalt Corporation
2540 South 27th Ave.
Broadview, IL 60153

G. V. Rao
Far-Mar-Co-Inc.
960 N. Halstead
Hutchinson, KS 67501

Mr. Jerry Rees
National Assoc. of Wheat Growers
Suite 1030
1030 15th St., N.W.
Washington, DC 20005

Louis P. Reitz
National Program Staff, ARS,USDA
Rm. 320, North Bldg., Arc West
Beltsville, MD 20705

Jim Reiva
Peavey Co.
11 Peavey Rd.
Chaska, MN 55318

V. R. Riley
Dept. of Civil Engineering
University of Toronto
Toronto, Ontario,
Canada M5S-1A1

Clarence Ritter
Turner, MT 59542

Robert L. Rizek
Consumer & Food Economics
ARS,USDA
Federal Center Bldg.
Beltsville, MD 20705

William W. Roath
Dekalb Agresearch, Inc.
2213 First Avenue North
Fargo, ND 58102

Robert O. Rogers
OA,ARS, USDA
Washington, DC 20250

Ole Sampson
North Dakota State Wheat
Commission
316 North 5th St.
P.O. Box
Bismarck, N D 58501

Dr. Lowell D. Satterbe
Dept. of Food Science &
Technology
Rm. 20, Filley Hall
University of Nebraska
Lincoln, NE 68503

William A. Scheller
Dept. of Chem. Engr.
University of Nebraska
Lincoln, NE 68503

G. W. Schiller
Dixie-Portland Flour Mills
P.O. Box 698
Arkansas City, KS 67005

Herbert J. Schmidt
Dekalb Agresearch, Inc.
2213 First Avenue North
Fargo, ND 58102

H. W. Schultz
Dept. of Food Science &
Technology
Oregon State University
Corvallis, OR 97331

Dennis Senft
USDA - ARS Western Region
2850 Telegraph Ave.
Berkeley, CA 94705

Abdelmonem Seyam
Dept. of Cereal Chem. & Tech.
N. Dakota State University
Fargo, ND 58102

John Sherlock
Millers National Federation
14 E. Jackson Blvd.
Chicago, IL 60604

William C. Shuey
Wheat Quality Lab, USDA
Dept. of Cereal Chem. & Tech.
North Dakota State University
Fargo, ND 58102

L. D. Sibbitt
Dept. of Cereal Chem. & Tech.
North Dakota State University
Fargo, ND 58102

George L. Smith
Kansas Farmer Magazine
719 Mills Bldg.
Topeka, KS 66502

Harry L. Stapleton
Seaboard Allied Milling Corp.
1550 W. 29th St.
Kansas City, MO 64108

Charles Storey
Grain Mktg. Research Center
USDA
1515 College Ave.
Manhattan, KS 66502

Donald F. Sundberg
Fisher Mills Inc.
3235 16th Ave., S.W.
Seattle, WA 98134

James L. Swanson
Peavey Technical Center
11 Peavey Rd.
Chaska, MN 55318

Victor H. Tanilli
Nabisco Research Center
2111 Route 208
Fair Lawn, NJ 07410

Raymond J. Tarleton
American Assn. of Cereal Chemists
3340 Pilot Knob Rd.
St. Paul, MN 55121

Marion Vaisey
University of Manitoba
Faculty of Home Economics
Winnipeg, Canada R3T 2N2

Mr. Eugene B. Vickers
Western Wheat Associates, Inc.
Suite 1008
1030 15th St., N.W.
Washington, DC 20005

Larry Warren
ADM Milling Company
Box 7007
Shawnee, Mission, KS 66207

Mr. J. S. Wenzel
The Griffith Laboratories, Ltd.
757 Parmacy Ave.
Scarborough 705
Ontario, Canada

John S. Whinery
Seaboard Allied Milling Corp.
1550 West 29th St.
Kansas City, MO 64108

Devoe H. Willard
National Wheat Institute
1030 15th St.
Washington, DC 20005

Dr. W. Woodbury
Dept. of Plant Science
University of Manitoba
Winnipeg Manitoba, Canada

J. W. Wright
RFD
Webster, ND 58382

W. T. Yamazaki
Soft Wheat Quality Lab
ARS,USDA
Ohio Agr. Res. Dev. Ctr.
Wooster, OH 44691

Western Regional Research Center, Agricultural Research Service,
U.S. Department of Agriculture, Albany, CA 94710

Maura Bean
John E. Bernardin
H. P. Binger
David A. Fellers
John W. Finley
Robin M. Saunders

Northern Regional Research Center, Agricultural Research Service
U. S. Department of Agriculture, Peoria, IL 61604 61604

R. J. Dimler
Dwight L. Miller
Wilbur C. Schaefer
Arthur Stringfellow
R. E. Wing
Y. Victor Wu

Applicants for all Department programs will be given equal consideration without regard to race, color, sex, creed, or national origin.

☆ GPO 690-563

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
Western Regional Research Center
800 Buchanan Street
Albany, California 94710

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF AGRICULTURE

AGR-101